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# LIGHT RAILWAY CONSTRUCTION

BY

RICHARD MARION PARKINSON

ASSOC. M. INST. C.E.

WITH 85 DIAGRAMS

LONGMANS, GREEN, AND CO.
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# PREFACE

THIS work is intended as a book of reference for the use of engineers in practice and their pupils and assistants.

The Author, having himself experienced the want of a practical office manual, has endeavoured to provide a text-book which, though primarily intended for those engaged in constructing light railways, may be more or less helpful to all who are employed on public works, whatever may be their nature.

He has to express his thanks to Mr. Basil Mott, one of the engineers of the Central London Railway, for his help with the part of the work relating to iron subways; to the Secretary of the Institution of Civil Engineers for the information he has gleaned out of the Minutes of Proceedings; and to Mr. R. A. Read, of Parliament Street, solicitor, for his assistance in the chapter on the preparation of the plans for Deposit.

PETERBOROUGH,
*September*, 1902.

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# INTRODUCTION.

**Definition of a light railway—Analysis of the items of expense—Continental, Indian, Colonial, and American railways—Grading and laying out American lines—Difference between a light railway and the ordinary construction.**

WITH a view of extending railway communication to agricultural and other districts, which are not rich enough to pay a fair return for the large cost of such lines as are usually constructed in this country, an Act of Parliament was passed in the year 1896 authorizing the making of Light Railways.

It is natural that the initial question to present itself to the mind should be—"What is a Light Railway, and how can it be constructed to cost less than the ordinary railway?"

To answer this it is necessary to analyze the various items of expense, and these may, under ordinary circumstances, be put under twelve heads—

1. Preliminary work in preparing the plans, book of reference, estimates, and draft-bill or order, publishing the notices, and making the necessary cash deposit.
2. Proceedings before the Parliamentary Committees, or Commissioners, as the case may be, including Parliamentary fees, and also the fees and expenses of witnesses, counsel, and solicitors.
3. Raising the capital.
4. Land, and compensation for severance, damage, etc.
5. Fencing.
6. Earthworks.
7. Public and private bridges, roads, and level crossings, gatekeepers' houses, tunnels, viaducts, and retaining walls.
8. River bridges, culverts, and drains.
9. Permanent way and ballast.
10. Telegraph, signals, and locking gear.
11. Station yards, platforms, and buildings.

12. Rolling stock—including engines, carriages, trucks, running and repairing sheds, and electrical or other working equipment.

1. An act, or rather an order, cannot be obtained where there is a competing line or any strong opposition, and so there is not the same object in waiting till the last minute before commencing the plans; indeed, it is necessary to consult with all those concerned in order that all possible objections may be met. Again, an application for a Light Railway may be made, not only in November, but also in May, when the days are longer, the weather usually better, and both engineers and lithographers less busy. The plans can, therefore, be prepared for rather less money. The cash deposit of 5 per cent. need not be made before the inquiry, but only just before the works are commenced, and this is a much simpler matter.

2. A bill for a Railway has to be read three times and is often a week before the committee in each House, to say nothing of the days it is set down for consideration and does not come on; whereas, a Light Railway is generally disposed of in a day by the Commissioners, one counsel instead of three being employed, and expense saved in local witnesses' expenses by the inquiry being held on the spot. The £50 fee charged is also very much less than the Parliamentary fees. On the other hand, unnecessary expenses are sometimes incurred through its not being known till the last minute if a line is going to be opposed or not, no notice of opposition being necessary.

3. Local authorities, who are able to raise money at 3 per cent. on the security of town or county rates, instead of the 5 per cent. that a new company would have to pay, may promote, or assist in promoting, a line, and the Treasury may, under certain conditions, also lend money. The effect of this in reducing the cost is very considerable.

4. Trustees may *give* land or accept less than its actual value in payment with the consent of the Board of Agriculture, and arbitrators may take into consideration the improved value of estates in fixing the amount for compensation.

5. The same kind of fencing is required, as a rule, and it is only in exceptional cases that it can be dispensed with.

6. The speed being limited the curves may be sharper, and in some cases the gradients steeper, and so earthwork may be saved.

The formation width can only be slightly reduced, and the slopes not at all, and they must be soiled in the usual way. As more level crossings are allowed, a considerable saving can often be effected in the raised or sunk approaches and the corresponding cuttings or banks on the railway where roads are crossed. Curves, however, lengthen a line, and steep gradients sometimes necessitate a heavy permanent way to carry the larger engines which are required to work them, so that a saving in the works may mean extra expenditure in the permanent way, rolling stock, and working.

7. A considerable saving can generally be effected in respect of bridges, etc., especially near stations and valuable property.

8. With light rolling stock large-span river bridges can be cheapened; but there is not much saving to be looked for here except as to the reduced cost of culverts, which, under the smaller banks, need not be so strong, and a yard in length is saved by every foot a bank is reduced in height.

9. Less ballast and a lighter permanent way are usually put, a flanged rail being good enough for light loads and low speeds; but, as has been said before, heavy rails must be used to carry the heavy engines that are required for drawing paying loads up steep gradients.

10. The same interlocking system is not required except at crossing stations, but even here distant and starting signals can generally be dispensed with.

11. Station buildings and platforms are not actually *required* by the Act, but in most cases something *ought* to be put.

12. The rolling stock for short distances and low speeds need not be so comfortable or expensive as for main-line traffic, and a very small quantity need only be provided in the first instance.

Railways on the continent, in India, the colonies, and particularly in America, are commonly constructed at much less cost than in this country, and it is well to consider in the first place how this is done.

On the continent generally the traffic is less, and so a lighter permanent way, very low platforms, and a less complicated system of signalling are found to suffice; but more money is often spent on station buildings, and the wide space between the lines means extra land in places where this is especially valuable; this space, for example, being at the Berlin metropolitan stations 9 feet 6 inches.[1]

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[1] *Proc. Inst. C.E.*, lxxx. 372.

In India the gauge is wider and the lines are well ballasted and fenced, and ample station accommodation is provided; but the rails are rather lighter, and the banks are generally made from side-cuttings, the earth being carried on the heads of natives in baskets, it being better to employ cheap labour than too much plant, where land is cheap. Against the saving in this respect, however, comes the cost of the bridges over rivers, dry at one time but torrents at another, where the foundations have to be taken to a great depth. About one-third of the railways are on the metre gauge, of which more will be said hereafter. The following table shows that the system of construction does not much differ from that in use at home, except in the weight of the engines and the depth and width of the ballast:—

GOVERNMENT REGULATIONS FOR RAILWAYS IN INDIA.[1]

| | 5′ 6″ gauge. | | Metre gauge. | |
|---|---|---|---|---|
| | Ft. | In. | Ft. | In. |
| Centre to centre of tracks in open country | 12 | 0 | 12 | 0 |
| „ „ „ station yards | 15 | 0 | 13 | 0 |
| Minimum radius—ordinary country | 1500 | 0 | 1000 | 0 |
| „ „ difficult „ | 800 | 0 | 600 | 0 |
| Depth of ballast below sleepers' base | 0 | 8 | 0 | 6 |
| Width of ballast at sleepers' top | 10 | 6 | 7 | 0 |
| Height of passenger platforms above rail-level | 3 | 0 | 1 | 3 |
| „ goods „ „ „ | 3 | 6 | 2 | 3 |
| Minimum length of platform | 600 | 0 | 500 | 0 |
| Clear length of crossing siding | 1600 | 0 | 1300 | 0 |
| Formation width of embankment for single line | 20 | 0 | 16 | 0 |
| „ „ cutting, exclusive of side drains | 18 | 0 | 14 | 0 |
| Maximum width of loading gauge | 10 | 6 | 8 | 6 |
| „ height „ „ at centre | 13 | 6 | 11 | 0 |
| „ „ „ „ at sides | 11 | 6 | 9 | 6 |
| Height of the centre of buffers above rail-level | 3 | 6 | 1 | 10 |
| | Tons. | | Tons. | |
| Distributed load for a span of 20 feet | 46 | | 35 | |
| „ „ „ 40 „ | 90 | | 60 | |
| „ „ „ 60 „ | 107 | | 78 | |
| „ „ „ 100 „ | 160 | | 110 | |
| Maximum load on an axle—engines | 12 | | 7 | |
| „ „ „ carriages and waggons | 8 | | 4·5 | |
| | lbs. | | lbs. | |
| Weight of rail per lineal yard | 62 | | 42 | |
| | Number. | | Number. | |
| Sleepers per mile | 1760 | | 2000 | |
| | Feet. | | Feet. | |
| Length of sleepers | 10 | | 6 | |
| | Inches. | | Inches. | |
| Size „ | 10 × 5 | | 8 × 4 | |
| | Rate. | | Rate. | |
| Maximum gradient—ordinary country | 1 in 150 | | 1 in 150 | |
| „ „ difficult „ | 1 in 50 | | 1 in 50 | |

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[1] *Proc. Inst. C.E.*, xcvii. 113 and 117.

On the Ceylon Government Railway, 5 feet 6 inches gauge, there is a gradient of 1 in 44 for 60 miles eased on the curves of 5-chains radius, of which there are several, one being 18 chains long, to 1 in 51. To work this line the engines had no flanges on their leading wheels, and bogies were everywhere used. The platforms were made 200 feet long, 10 feet wide, and 18 inches high.[1]

In New South Wales the gauge is 4 feet 8½ inches, the sharpest curve 8-chains radius, and the steepest gradient 1 in 30 for long distances. The formation width is 15 feet, and the bottom ballast 8 to 12 inches thick.[2]

On the Cape Government Railways the gauge is 3 feet 6 inches, the steepest gradients 1 in 40, and the sharpest curves 7-chains, and in a few cases 5-chains radius. The lines are mostly not fenced. The rails weigh 45 lbs. per yard, and the 6-coupled engines 30 tons, with 10 tons per axle, and the usual speed is 15 miles an hour, reduced to 10 on the heavy gradient.[3]

On the 3 feet 6 inches gauge in South Australia the ruling gradient is 1 in 60, the sharpest curve 5-chains radius, and the formation width 12 feet 6 inches in cutting 14 feet on bank.[4]

In America, instead of land having to be bought, large land grants are often made. The universal use of bogies and flangeless wheels[5] for some of the engine driving-wheels enables curves of very small radius to be employed, but, owing to the heavy loads drawn, steep gradients are no more admissible than here, although high speeds are not considered so important.

Very heavy gradients are, however, employed in some places, and for these engines with a heavy load on their driving-wheels are required. The gradients are "bunched" as much as possible—that is to say, they are so brought together that they may be contained in one engine stage of 60 to 100 miles, since it is economy for one of the ordinary engines to be able to take a train of maximum length over the more level portions of the line, and for a heavier one, or, if necessary, two, or even three, to take it up the steeper gradients.[6] Where the heavy locomotives are employed, it is necessary to have a heavier permanent way and stronger bridges. It is, therefore, economy to make the bridges and permanent way of the level portions of sufficient strength for the lighter engines and the heaviest cars, and just that part where the bad gradients are situated of a stronger character, provision being of course made for repairing the heavy engines on their own section.

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[1] *Proc. Inst. C.E.*, lxiii. 74.

[2] *Ibid.*, lxxxv. 154.

[3] *Ibid.*, lxxxi. 252.

[4] *Ibid.*, lvi. 33.

[5] *Ibid.*, lxxxv. 54, 178.

[6] *Ibid.*, lxxxv. 82, 189.

The rolling stock is being brought as much as possible to standard types and the gauge to 4 feet 8½ inches, although there is still a good deal of the 3-foot gauge. The engines have four, six, eight, and ten wheels coupled together, single drivers being hardly ever used.[1] The usual load on an axle is from 10 to 15 tons, the maximum 18 tons. The ordinary load per foot run of single line for the entire length of an engine (buffer to buffer) may be put at 1½ tons, and the extraordinary load, due to the heaviest engines, 1¾ tons. Freight cars 28 feet long, weighing when loaded 36 tons, are employed. They rest on two bogies, thus giving a load of 9 tons per axle, and of 1¼ tons per foot run of single line for the whole of their length buffer to buffer. From this it appears that it is economical to provide bridges and permanent way for a rolling load of 1¼ tons per foot run of single line, and of 12 tons per axle on those sections of the line where the gradients are easy or over 1 in 100, and to allow for loads of 2 tons per foot run and 20 tons per axle on the heavier sections.

The ton spoken of here, and in all cases in this work, is the English ton of 2240 lbs., and not the American short ton of 2000 lbs.

Girders are made deeper than in England. For large spans pin connections are generally employed. No ballast is laid over the span, and even the flooring is not always continuous, and thus some dead weight is saved. The ironwork for the bridges is not usually designed by the engineer, but designs are submitted by the firms tendering, in accordance with the general plans and specification.

When a line is first constructed, timber trestle-work is often employed, and if some judgment is exercised, a considerable saving in time and cost can be effected by means of it, and the bridges can be reconstructed in iron when the timber fails, which would be in 8 or 10 years, and then the girders can be brought on to the spot at much less cost. Trestle-work is also employed as a substitute for embankments in some cases, and the banks are made up afterwards.

Steel Vignoles rails about 4 inches wide and 4½ inches high, of

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[1] *Proc. Inst. C.E.*, lxxxv. 63.

56 to 70 lbs. per yard, are generally used. They are properly fished and spiked to 8-inch by 6-inch sleepers, 8 or 9 feet long, 2800 to the mile, or closer than in England. In many places there is no ballast at all.

Fencing is hardly ever put unless the country is settled, and then only if it is specially asked for, when it consists of four lines of barbed wires.

There are very few road bridges, streets, even in large towns, being crossed on the level without gates.

The lines are often constructed more as "overland routes"—that is to say, they follow the surface of the ground as far as possible; but gradients of more than 1 in 100 are mostly avoided, although sometimes 1 in 46 and even 1 in 22 have had to be adopted, and these in conjunction with sharp curves.

In many cases the banks are formed from side-cuttings, and the cuttings run to spoil, but, to avoid snow-drifts, in certain districts, the latter are less common than banks. The banks are more often made up by "scrapers" or "graders" than by hand labour, a scraper being capable of depositing from 60 to 100 yards in a bank in a day, and a grader 800 yards.

Where heavy gradients occur on sharp curves they are compensated to make the necessary traction the same. Opinions differ as to the amount of compensation necessary, but it is commonly taken at 0·05 per 100 feet for 1° of curve.[1]

Curves are made as easy as possible, and a sharper radius than 7 chains is uncommon.

Very little is spent on depôts or stations, the platforms usually being made about 200 feet long, 6 to 12 feet wide, 15 inches above rail-level, and 5 feet 6 inches from the centre of the track, while the points and signals are not locked.

Most of the lines are only single.

In laying out a line the mode of proceeding is as follows, there being generally no reliable maps to work from:—

A surveyor with the theodolite stakes out a series of straight lines, putting in pegs 100 feet apart in such directions as are pointed out by his chief, who is exploring in advance. Another surveyor then takes the levels of these pegs, and a third the cross-sections at them, sometimes by means of a clinometer. The work is plotted every night, so that the proper direction for the next day's work may be ascertained. In this way from 1 to 2 miles may be located in a day by the help of a number of chainmen, called "rodmen," and others acting as axemen, cooks, and luggage carriers. To fix a line properly with any amount of speed, there are of course a number of different parties.[1]

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[1] *Proc. Inst. C.E.*, lxxxv. 71, 167.

In construction some thirty miles are put under the charge of a divisional engineer, who has perhaps three assistants, one to each 10 miles, and each of these in turn has his rodman, axeman, and cook, the assistants' duties being to give the lines and levels. When the divisional engineer's section is finished, he moves on with his staff to another section.

The speed at which lines can be made is considerable, large numbers of men and horses being employed, and 4 miles of track are often laid in a day.[2]

In constructing a line the materials are unloaded at the end of the track from the material train; they are then picked up on trollies and run forward, each pair of rails being laid in advance for these to run on, and when each is cleared, it is thrown off the road for another similarly loaded to pass it. The necessary number of sleepers, etc., are of course taken forward at the same time.

The track-layers sleep in and are provisioned by a train which comes up and remains at the head of the track during the night, and is put by in a siding during the day, but provisions for the graders (or excavators) have to be carted forward.

It is obvious that we cannot expect to compete, in the matter of economy, with the American and other lines, which are laid out in undeveloped countries where land is practically valueless and fencing is not required; but with these examples before us we can look at the matter in a clearer light.

The main things to be considered are the gauge between the rails, the height and width of the rolling stock, the weight of the rolling stock and the consequent strength of the bridges and permanent way, the maximum speed and minimum radius for the curves, and the greatest and average gradients. These points will be dealt with in Chapters I., VII., and XII.

Something of what has been done on the continent and elsewhere will be gathered from Appendix H, which has been compiled from information gathered almost entirely from the *Minutes of Proceedings of the Institution of Civil Engineers.*

[1] *Proc. Inst., C.E.*, lxxxv. 88.

[2] *Ibid.*, lxxxv. 119.

In some respects a light railway is like any other railway, but there are fewer works. Readers who want further information on railway construction are referred to the larger work in this series by Mr. Mills, which gives illustrations of a hundred bridges and tunnels and fifty or sixty stations and roofs, this volume only professing to deal with the lighter works that are commonly encountered.

# CHAPTER I.

## *GAUGES, CURVES, AND GRADIENTS.*

**Transhipping—Saving by employing a narrow gauge—Low construction and end instead of side doors—Minimum radius for fast and slow travelling—Compensation for curves in gradients—Tractive force—Train resistance—Table of gradients and loads—Steep inclines—Gravitation sidings—Effect of gradients on speed—Examples of heavy gradients.**

THERE is a little misunderstanding as to the effect of employing a narrower gauge than the standard of 4 feet 8½ inches, both as regards the inconvenience caused by the necessary transhipping and the economy that can be effected in first cost.

Even with railways of the standard gauge, although many things go right through to their destination in one truck, there is a large amount of transhipping necessary, especially in the case of passengers and small goods, so that a change of gauge is not so serious a matter as appears at first sight.

Their owners object to cattle being transhipped, coal breaks a little, and other things are liable to be damaged, but the actual cost of transhipment is small, if proper appliances are provided.

On the other hand, the saving effected by employing a narrow gauge is not as great as might be expected. Gradients and curves may be made as sharp with the 4 feet 8½ inches gauge as with the 3-foot, and the rolling stock, and consequently the permanent way and bridges, may, within certain limits, be made as light. There is hardly any saving in land or earthwork. It is really only in the bridges, ballast, and sleepers that the gain comes in. If, however, a line is not made strong enough to take the ordinary rolling stock, there might just as well be a break of gauge. The best construction seems to be a line that will carry an ordinary coal-waggon with 7 or 8 tons on an axle worked by six-coupled 24-ton engines with a load-gauge which would only just take a cattle-waggon, as in Fig 1, or, if there is but little cattle traffic, only a coal-waggon, as in Fig. 2, in cases where there are many over-bridges or tunnels and the reduction of headway is a great object. The floors of the passenger carriages need only be 1 foot 8 inches above the rails, and the tops only 8 feet 4 inches, as on the City and South London Railway,[1] and, as they can be entered from the ends, provision for open doors need not be made, so that the minimum structures may be reduced from 14 feet wide and 14 feet 6 inches high to 10 feet wide and 10 feet high. Comparing the 3-foot gauge with a standard gauge of this type, in the case of an easy line, there is but a saving of from 5 to 10 per cent. (in land, earthworks, ballast, and sleepers) in all in favour of the former.

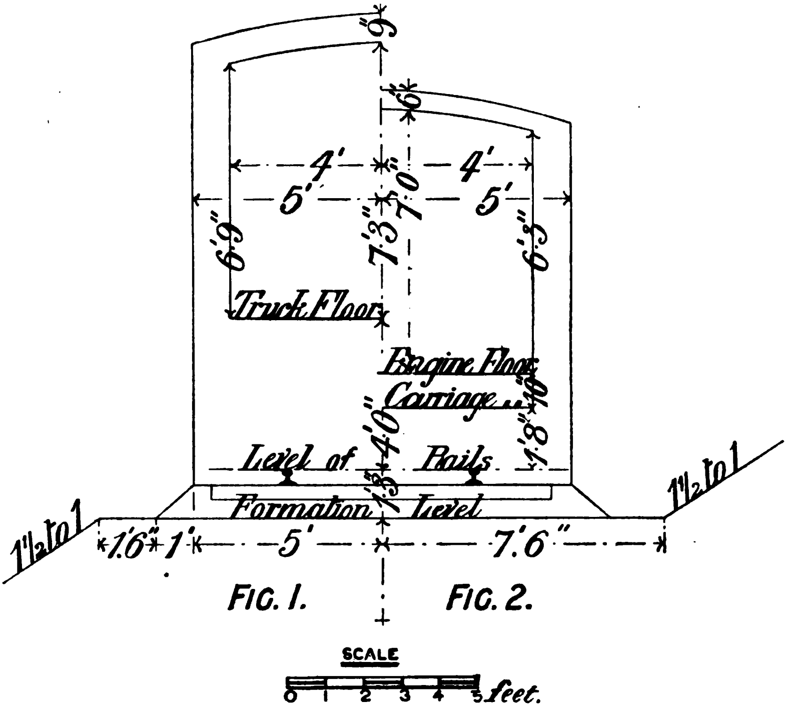

FIG. 1. FIG. 2.

There is a very much larger saving if a 2-foot or 3-foot gauge with a very light rolling stock is adopted, especially if it can be laid by the side of the public roads in places where there is room for it, and not for the 4 feet 8½ inches line, as there often is; but the roads must have suitable gradients, for a light engine is useless on heavy inclines, and cuttings or embankments cannot often be made in the cess by the side of the road.

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[1] *Proc. Inst. C.E.*, cxxiii., Plate 2.

A 2-foot gauge is perhaps hardly safe for passengers, but with little iron waggons, which can tip their contents into the larger trucks, as in Fig. 3, it is useful in many cases.

The 3-foot, and sometimes the 4 feet 8½ inches, line can often be laid between the metalled part of the road and the hedge, and can be worked as a tramway, no land, earthworks, fencing, bridges, or stations being wanted, and no paving having to be laid, as in the case of a tramway.

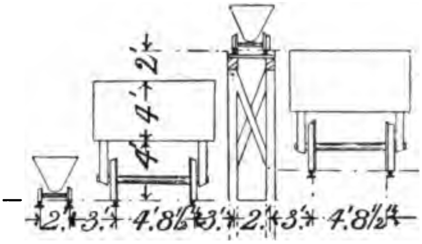

FIG. 3.

No general rules as to the best kind of line to adopt can be given, as there are always special circumstances to be considered in each case; but the following table, which gives an idea of the average cost in pounds per mile of single line of the various classes, will be found to be useful:—

| Description. | Railway. | Light railway. | | | | | |
|---|---|---|---|---|---|---|---|
| Gauge . . . . . . . | 4' 8½" | 4' 8½" | 4' 8½" | 3' 0" | 3' 0" | 3' 0" | 2' 6" |
| If laid by the side of the road or not | No | No | Yes | No | No | Yes | Yes |
| Weight of rail in lbs. per yard | 84 | 56 | 56 | 56 | 28 | 28 | 14 |
| | £ | £ | £ | £ | £ | £ | £ |
| Preliminary work . . . | 250 | 100 | 100 | 100 | 100 | 100 | 100 |
| Land . . . . . . . | 1500 | 400 | 100 | 350 | 350 | 30 | 25 |
| Fencing . . . . . . | 400 | 400 | 100 | 400 | 400 | 30 | 25 |
| Earthworks . . . . . | 800 | 400 | 100 | 350 | 350 | 50 | 30 |
| Bridges and culverts . . | 1200 | 300 | 50 | 250 | 250 | 30 | 20 |
| Level crossings . . . . | 100 | 100 | 50 | 100 | 100 | 40 | 30 |
| Permanent way . . . . | 2280 | 1380 | 1380 | 1220 | 760 | 760 | 520 |
| Stations, signals, and telegraph | 470 | 220 | 120 | 130 | 90 | 60 | 50 |
| Total. . . | 7000 | 3300 | 2000 | 2900 | 2400 | 1100 | 800 |

In this the land for the ordinary railway has been put at £250 per acre and for the light line at £100. If the line runs along the centre of the street, it has to be paved, and heavier rails must be used. This means an extra of £3000 per mile in the case of the 4 feet 8½ inches gauge and of £2400 in the case of the heavy 3-foot gauge.

**Curves.**—There is no objection to a curve of 40-chains radius under any conditions as regards safety or speed, but for main lines anything less than this has to be avoided, and a good length of straight must separate reverse curves.

A radius of 20, or even 10 chains, can safely be employed where the speed is not likely to be high, and in goods yards even 6 chains is not considered too sharp, but this is the limit for lines on which six-wheeled engines are employed. It is possible for four-wheeled vehicles, or those with bogies, to get round curves of even less than a chain radius, but it is necessary for the speed to be very slow and the tractive power great. Sharp curves, *i.e.* those of less than 10 or 20 chains radius, increase the resistance, while those of more than 40 chains hardly affect it, and the running on an easy curve is even steadier than on the straight; yet in spite of this, in laying out an important line it is common to adopt a radius of 80 chains for all curves, unless a considerable saving can be achieved by using 40 chains; but for light railways 10 chains may be employed as the minimum, and, where necessary, 7, 5, and even 3 chains—these last, however, only in cases where they are absolutely necessary.

It is the practice in America to compensate for curves in laying out the gradients. The curves are usually expressed by the degrees subtended at the centre by a chord of 100 feet, and a reduction in the gradient of 0·05 per degree in 100 feet is commonly made.[1] The gradients given in the table below should, therefore, be altered to those given under their respective headings.

| Curve. | Radius in feet. | Radius in chains. | 1 in 100. | 1 in 80. | 1 in 60. | 1 in 50. | 1 in 40. | 1 in 30. |
|---|---|---|---|---|---|---|---|---|
| 4° | 1432 | 21·70 | 125 | 95 | 68 | 55 | 43 | 32 |
| 6° | 955 | 14·47 | 143 | 105 | 74 | 58 | 46 | 33 |
| 8° | 716 | 10·85 | 166 | 118 | 80 | 62 | 48 | 34 |
| 10° | 573 | 8·68 | 200 | 133 | 86 | 67 | 50 | 35 |
| 12° | 477 | 7·23 | 250 | 154 | 94 | 71 | 52 | 36 |
| 14° | 409 | 6·20 | 333 | 182 | 104 | 77 | 55 | 38 |
| 16° | 358 | 5·42 | 500 | 222 | 116 | 83 | 58 | 40 |

**Gradients.**—Steep gradients affect the capacity of a line in two ways, to say nothing of its economical working. In the first place, they limit the number of vehicles that a train may be composed of; and in the second, the speed at which it can travel.

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[1] *Proc. Inst. C.E.*, lxxxv. 71.

The cost of working a short train is not much less than that of working a long one, as the same men must be employed, and, if the gradients are heavy in the one case and easy in the other, nearly as much fuel will be consumed. Again, as the speed is reduced by bad gradients, the line is occupied longer by each train, so that, particularly on single lines, the number of trains that can be passed in the day is much curtailed.

It is not possible to give any actual figures or formulæ to find what is the best gradient to employ, since the amount of traffic to be accommodated and other circumstances are generally unknown; what follows will, however, it is hoped, be some guide in the matter.

The tractive force exerted by an engine is generally acknowledged to be one-sixth of the weight on the driving-wheels.[1] Different experiments have given different results, but this may be taken as a reliable figure. The engine must, of course, be in proper proportion; but, however strong its steaming powers may be, it cannot exert a tension of much more than the one-sixth, for the wheels will slip, owing to the frictional resistance of steel on steel being exceeded.

In England it is not usual to couple more than three pairs of wheels, and thus the tractive force is at once limited by the strength of the permanent way and under-bridges.

The average resistance of a train on the level is 10 lbs. per ton, but many vehicles will move with a force of 8½ lbs., which is the same thing as saying that they will start by themselves on a gradient of 1 in 264. Some trucks require a force of 20 lbs. per ton to start them, and sharp curves cause an additional resistance of something like 10 lbs.

The following table gives the loads that certain engines will take up different inclines on easy curves and the straight, and also on sharp curves. It has been calculated on the preceding basis, viz. that an engine will exert a tractive force of one-sixth the weight on its driving-wheels, and that the resistance of a train on easy curves is 10 lbs. per ton of its weight, and on sharp curves 20 lbs.; the resistance on a 1 in 30 gradient in the latter case being thus $W(\frac{20}{2240} + \frac{1}{30})$ in tons, where W is the gross weight of the train and engine.

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[1] *Proc. Inst. C.E.*, lxxxv. 82, 192; and lxiii. 138.

|  | 4-coupled with 6 tons on each axle. |  | 6-coupled with 6 tons on each axle. |  | 4-coupled with 8 tons on each axle. |  | 6-coupled with 8 tons on each axle. |  | 4-coupled with 12 tons on each axle. |  | 6-coupled with 12 tons on each axle. |  | 4-coupled with 16 tons on each axle. |  | 6-coupled with 16 tons on each axle. |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight of engine and brake | 30 tons |  | 30 tons |  | 36 tons |  | 36 tons |  | 48 tons |  | 48 tons |  | 60 tons |  | 60 tons |  |
| Gradient. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. | Total load. | No. of vehicles. |
| Easy curves. | Tons. |  | Tons. |  | Tons. |  | Tons. |  | Tons. |  | Tons. |  | Tons. |  | Tons. |  |
| 1 in 20 . . . . . . . . | 36 | 0 | 54 | 2 | 48 | 1 | 72 | 3 | 72 | 2 | 108 | 5 | 96 | 3 | 144 | 7 |
| 1 „ 30 . . . . . . . . | 53 | 2 | 79 | 4 | 71 | 3 | 106 | 6 | 106 | 5 | 158 | 9 | 142 | 7 | 212 | 12 |
| 1 „ 40 . . . . . . . . | 67 | 3 | 101 | 6 | 90 | 4 | 135 | 8 | 135 | 7 | 202 | 13 | 181 | 10 | 270 | 17 |
| 1 „ 50 . . . . . . . . | 81 | 4 | 122 | 8 | 109 | 6 | 163 | 10 | 163 | 9 | 244 | 16 | 218 | 13 | 327 | 22 |
| 1 „ 60 . . . . . . . . | 95 | 5 | 142 | 9 | 126 | 7 | 189 | 12 | 189 | 11 | 284 | 19 | 252 | 16 | 378 | 26 |
| 1 „ 80 . . . . . . . . | 117 | 7 | 176 | 12 | 157 | 10 | 235 | 16 | 235 | 15 | 352 | 25 | 314 | 21 | 470 | 34 |
| 1 „ 100 . . . . . . . . | 138 | 9 | 207 | 15 | 184 | 12 | 276 | 20 | 276 | 19 | 414 | 30 | 368 | 25 | 552 | 41 |
| 1 „ 200 . . . . . . . . | 210 | 15 | 315 | 24 | 281 | 20 | 421 | 32 | 421 | 31 | 631 | 48 | 562 | 42 | 842 | 65 |
| Sharp curves. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 in 20 . . . . . . . . | 34 | 0 | 51 | 2 | 45 | 1 | 68 | 2 | 68 | 2 | 102 | 4 | 90 | 2 | 136 | 6 |
| 1 „ 30 . . . . . . . . | 48 | 1 | 71 | 3 | 63 | 2 | 95 | 5 | 95 | 4 | 143 | 8 | 126 | 5 | 190 | 11 |
| 1 „ 40 . . . . . . . . | 59 | 2 | 88 | 5 | 78 | 3 | 117 | 6 | 117 | 5 | 175 | 10 | 156 | 8 | 234 | 14 |
| 1 „ 50 . . . . . . . . | 69 | 3 | 103 | 6 | 92 | 4 | 138 | 8 | 138 | 7 | 207 | 13 | 184 | 10 | 276 | 18 |
| 1 „ 60 . . . . . . . . | 78 | 4 | 117 | 7 | 104 | 5 | 156 | 10 | 156 | 9 | 234 | 15 | 208 | 12 | 312 | 21 |
| 1 „ 80 . . . . . . . . | 93 | 5 | 140 | 9 | 124 | 7 | 186 | 12 | 186 | 11 | 280 | 19 | 248 | 16 | 373 | 26 |
| 1 „ 100 . . . . . . . . | 106 | 6 | 160 | 11 | 141 | 8 | 212 | 14 | 212 | 13 | 320 | 22 | 283 | 18 | 423 | 30 |
| 1 „ 200 . . . . . . . . | 143 | 9 | 215 | 15 | 191 | 13 | 286 | 21 | 286 | 20 | 430 | 32 | 383 | 27 | 572 | 43 |

Assumed weight of each vehicle, 12 tons.

As a check on this table, it may be mentioned that on the West of India Portuguese Railway a 43-ton engine, with 27 tons on the drivers, has been shown to be able to take thirteen vehicles, equal to 117 tons, up an incline of 1 in 40, on which there are curves of 800-foot radius; while two engines will take up twenty-four vehicles, equal to 216 tons, at 5 miles an hour, the speed on the level being generally 20 miles an hour.[1]

An engine with eight wheels coupled, weighing 74 tons, of which 46 tons were on the driving-wheels, took a load of 125 tons up the 1 in 22 gradient at 4½ miles an hour.

With a gradient of 1 in 14, a 36-ton engine, with all its weight on the driving-wheels, can just draw a load equal to its own weight, and one of 1 in 6 it can only just ascend alone, this being nearly the angle of friction of steel upon steel. If it is desired to ascend such an incline as this by simple adhesion, the engine and car must be in one, with the whole weight on the driving-wheels. Owing to the space taken up by the boiler and machinery, in the case of an ordinary steam locomotive this cannot well be managed, but with compressed air or electricity it is easier.

For steeper gradients than this it is necessary to employ a rack or, if the line is not very curved, a rope.

It is, of course, not wise to introduce heavy gradients which have to be worked in a special manner if they can be avoided, but in some cases they may cause such a saving in first cost as to make them advisable, and in others they may be absolutely necessary.

In laying out the gradients for gravitation sidings, care must be taken to give a sufficient inclination to start the worst running trucks. Now, if this is made 1 in 100, it will overcome a resistance of 22·4 lbs. per ton, and very few trucks give more than this on easy curves. On sharp curves, however, the additional resistance of 10 lbs. or 32·4 lbs. in all, must be allowed for, and this will be overcome by an inclination of 1 in 70. In a paper by the writer on this subject, published in vol. cii. p. 249, *Proc. Inst. C.E.*, these figures were called in question, and to prove the first statement, he took four trucks at random out of a station yard, and each started at once on the 1 in 100 gradient. Opinions somewhat differ on the subject, but the gradients generally adopted vary from 1 in 85 to 1 in 110; 1 in 70 and 1 in 80 being employed amongst curves and where the road is in bad order. Those on the London and North-Western Railway at Edge Hill vary from 1 in 60 to 1 in 100, according to their position. Perhaps 1 in 88 on the straight and 1 in 66 on sharp curves are the best inclinations—at any rate, for that portion of the line where the trucks are started.

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[1] *Proc. Inst. C.E.*, xcvii. 314.

By laying out the sidings or siding at a wayside station with proper gradients, a good deal of money may be saved in the length of loading docks, etc., and in the cost of working, so a proper understanding of this subject is important.

With reference to the effect of a gradient in checking the speed of a train, some experiments made on the Brighton line will be interesting.[1]

It was found that a 60-ton engine with twenty-three 12-ton coaches travelled at a speed of—

| | | |
|---|---|---|
| 55 | miles an hour | on the level |
| 60 | „ „ | down 1 in 264 |
| 45 | „ „ | up 1 mile of 1 in 264 |
| 40 | „ „ | „ 3 miles of 1 in 264 |

The tractive force at starting was 44 lbs. per ton; when going up the 1 in 264, 22 lbs.; and when running down it, 11 lbs.

A heavy Great Northern express, running at 60 miles an hour, was pulled up, by a long length of 1 in 200, to 36 miles an hour; and in another case a light train, by some miles of 1 in 100, to 30 miles an hour, and a goods train, of fourteen waggons, to 17 miles an hour.

The effect of such gradients as 1 in 60 and 1 in 40 can from these cases easily be imagined, and with a heavy load the speed would probably be under 10 miles an hour.

The following may be given as instances of specially heavy gradients worked in the ordinary way by simple adhesion:—

| | | | |
|---|---|---|---|
| Mersey Railway | 1 in 30 | for 35 chains | |
| „ „ | 1 „ 27 | „ 18 „ | |
| Canadian Pacific | 1 „ 22·2 | „ 3 miles | |
| „ „ | 1 „ 46 | „ 4½ „ | |
| Union Pacific | 1 „ 33 | „ 1½ „ | |
| Ceylon | 1 „ 44 | „ 18 „ | |
| Great Western Railway | 1 „ 40 | „ 6 „ | (not continuous) |
| „ „ | 1 „ 50 | „ 45 „ | „ „ |

To rise to the proper level the St. Gothard Railway ascends by means of circular tunnels like a corkscrew, and so extremely heavy gradients are avoided. For a light railway, however, it is better to have a heavy gradient and divide the train; thus, on a line where the ruling gradient adopted was, say, 1 in 50, there would not be much inconvenience caused by introducing a short piece of 1 in 30, for a six-coupled engine with 12 tons on each axle, which could take sixteen 12-ton trucks up the 1 in 50, could surmount the 1 in 30 with half its load at a time.

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[1] *Prcc. Inst. C.E.*, lxxxi. 108.

Some further examples of specially heavy gradients are given in Appendices H and I.

# CHAPTER II.

## *PREPARATION OF THE PLANS FOR DEPOSIT.*

**Board of Trade Rules—Information for solicitors—Notice—Order—Preliminary survey—Scales—The Plan—Enlargements—Limits of deviation—Centre line—Furlong-points—Proofs—Book of Reference—The section—Levelling—Plotting—Grading—Deposits—Tramways—Provisional orders—Subways.**

THE first thing to be borne in mind in connection with the preparation of the plans and sections, herein referred to as the **Plans**, is that they must be deposited at the places required by the rules of the Board of Trade, on or before the last day of the month in which the notices are published, or the day before if the last day of the month is a Sunday, and that no postponement of this date is possible. Consequently, it is important at the outset to arrange with the solicitors the place and the latest possible time at which the completed plans may be handed over ready for deposit, and to avoid responsibility the engineer must strictly adhere to whatever arrangement is come to.

The next thing to be remembered is that the "Rules of the Board of Trade" require that the notice of the intended application, which has to be published in the papers, shall give certain information as to the nature of the proposed railway and works, and that the engineer is responsible for obtaining the part of this information which is given below—

1. The general description of the course and of the termini of each railway, the latter points being so carefully defined that any one can localize their position without a possibility of error.
2. The names of the parishes, townlands, and extra-parochial places from, in, or through which any work is intended to be made, maintained, varied, extended, or enlarged, or in which any land or houses intended to be taken are situated.
3. The name of any common or commonable land and of the

parish in which it is situated, and the estimated quantity proposed to be taken.

4. The estimated quantity of land to be acquired and a general description of the purposes for which it is to be used.
5. The gauge.

The *latest* date for supplying this information to the solicitors varies from the 12th to the 19th of the month in which the notices are published, but the engineer should supply it at a much earlier date, so that, in case of any doubt arising, it may be cleared up in good time.

Failure to deposit the plans at the right time, the omission of the name of a parish in the notice, or a carelessly worded or inaccurate definition of the termini, would be fatal, and a fresh application would have to be made in the following May or November, as the case might be.

The positions of the termini can be fixed by referring to the numbers on the 25-inch ordnance maps if there are no other defined points.

The engineer has also to supply the information for filling in certain clauses in the draft order as to how the roads are to be dealt with and certain details as to construction, and he has to prepare the estimates. These clauses are given in Appendix D, and the form of the estimate in Appendix E, and it is to be noted that both the draft order and the estimate have to be deposited with the plans, and that, to give time for printing they must be completed in good time.

The process of preparing the plans for a light railway order is practically the same as in the case of an application for an Act of Parliament, but the engineer, subject to instructions from the promoters or their solicitors, should always consult the landowners and public bodies at this stage. There is not much risk of the line being opposed on the ground of non-compliance with the rules, but, nevertheless, just the same care should be taken as if the strongest opposition was to be expected.

Having received his instructions the engineer must, as a first step, provide himself with the best maps of the district that he can get. If the 6-inch ordnance sheets, with the levels and contours marked on them, are to be had, his task is very much lightened, as he can with the help of these, by simply walking over the ground, get a pretty good idea as to the best general route for the line. If the ordnance survey is not published[1] he must fall back on the parish plans usually obtainable in this country. These should be reduced to a common scale, which can easily be done by means of a pantagraph, and sufficient levels to give a general idea of the contours of the ground should then be marked thereon. If no plan at all exists a general survey must be made, but in this there is no necessity to fill in details.

The general route of the railway having been fixed, a number of surface-levels should be taken and marked on the plans that the centre line may be laid down more exactly. In preparing the plans for deposit, however, a very exact location is generally unnecessary, as the centre line may be deviated to any extent within certain limits, called the "limits of deviation," and when the order has been obtained surface-levels may be taken within these limits to fix it exactly. Unless they are intended also for the purpose of establishing bench marks, great accuracy in taking the surface-levels is unnecessary, and even errors of 1 or 2 feet and readings of 15 and 20 chains are admissible.

**Scales for the Plans for Deposit.**—In preparing the plans for deposit the first consideration is the scales to which they should be drawn.

The Board of Trade Rules require that the plan should be to a scale of not less than 4 inches to a mile, and unless the whole is drawn to that of 1 inch to 400 feet, an enlarged plan of every building, garden, yard, etc., must be given to at least this scale; hence, unless the country is very open indeed, it is better to draw the whole plan to this latter scale or, which is practically the same thing, to that of 6 chains to an inch.

As the standard size of the sheets when lithographed is 2 feet 6 inches long by 1 foot 10 inches wide, a distance of exactly 2 miles can be got into one sheet, otherwise, for the sake of uniformity, a scale of 5 chains to an inch would be the better one to use, as this is the smallest horizontal scale that may be used for the cross-sections.

In cases where the 25-inch ordnance can be had it becomes a matter for consideration as to whether it is better to deposit to this or to reduce. The writer prefers the former course, as there is a possibility of error in the reducing, and every possible risk of error should, in his opinion, be avoided.

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[1] Sometimes, when the ordnance survey is not published, tracings of it may be obtained from the Ordnance Survey Office, Southampton.

It sometimes happens that the 25-inch ordnance is not published, but that the 6-inch is. In this case, if the country is open, the 6-inch may be used, but it requires the very greatest care, especially when the ground is sidelong, as a very slight error in lithographing the plan will cause an error in the section. The tracings should, therefore, be very accurately made and the distances from the centre line to the fences checked on the proofs from the dimensions used in setting out. These distances should be measured from the *centre* of the centre line, as this generally scales fully a quarter of a chain in width. When from open country the line goes into a town, the plan need only show the roads and other main features, an enlargement of the whole being given; but it is perhaps better to stop the railway and commence a "Railway No. 2," which may be drawn to a different scale.

The section must be plotted to the same horizontal scale as the plan, and not to more than 100 feet to an inch vertical.

The cross-sections must be to not more than 5 chains to an inch horizontal, and 40 feet to an inch vertical.

The simplest and safest mode of proceeding is therefore to work to 4 chains to an inch horizontal and 40 feet to an inch vertical throughout, as there is then no chance of picking up the wrong scale; but there ought to be no mistake if 6 chains and 60 are used for the section, and 4 chains and 40 for the cross-sections.

The general conclusion to be drawn from what has gone before is, that when the 25-inch ordnance can be got, or, failing that, the 6-inch, it should be used; but when a new survey has to be made, it should be to 6 chains to an inch.

In towns even the 25-inch is sometimes too small to show everything, and it is necessary to employ the 5-foot and, sometimes, the 10-foot scale.

When the general plan is made to 6 inches to a mile, and an enlargement given right through a town for even a mile or more, the section must correspond with the general and not with the enlarged plan.

The vertical scale must be the same for all the railways in one order, and the datum line must also be the same.

For deposit it is more convenient to have the plan and section on different sheets, because the plan is generally done first and the section follows, and also because there are more distinct things to be looked at in correcting each proof. Of course, for after-reference, it is better to have plan and section together; but this is a small matter, for the sheets can easily be cut up and mounted.

**The Plan.**—It is unnecessary to describe the whole process of surveying or correcting the ordnance sheets out-of-doors, and so the following notes will suffice:—

When the ground is nearly level, great accuracy is not essential, but care must be taken where it is not, for the opponents to the order may take their measurements in setting out the line to check the levels from any fences within the "limits of deviation." Absolute accuracy in *measuring* details is also not required on *level* ground, but it is important that all fences, buildings, ponds, etc., should be *shown*. The division walls in houses need not be noted, unless they are divisions of property, and then it is the division lines on the *ground floor* that must be given. Where there is no physical division between the properties of different owners, or where they are only divided by hurdles or the like, the boundary should be indicated by a dotted line. It is unnecessary to give more than one line for a ditch, however wide it may be, unless it forms part of a system of drainage or irrigation.

Enlargements of every sort and kind of building, garden, and yard are required. It is not necessary to write the names of the parishes, etc., on these, nor to show the radius and furlong-points, but it is, perhaps, better to do so. On the general plan should be written, "See enlarged plan, No. —," and an arrow-head indicating to what this refers should be put.

Figs. 4 and 5 are intended to further explain what has gone before. Fig. 4 illustrates a whole sheet, one-fourth full size, drawn to the 25-inch scale, and Fig. 5, another whole sheet, drawn to the 6-inch scale.

It is important to use good paper for the lithographer's tracings. Very thin or bad tracing-paper will shrink, and give trouble with the furlong-points.

The centre line should first be laid down on the plan, and then the limits of deviation must be drawn, 4·50 chains from it, unless it is necessary to contract them to avoid property, or to extend them in order to get powers for purchasing extra land for road diversions, etc. Any property which has been referenced may be taken and the centre line deviated right up to the limit if necessary, but no land that has not been referenced may be touched, except by agreement.

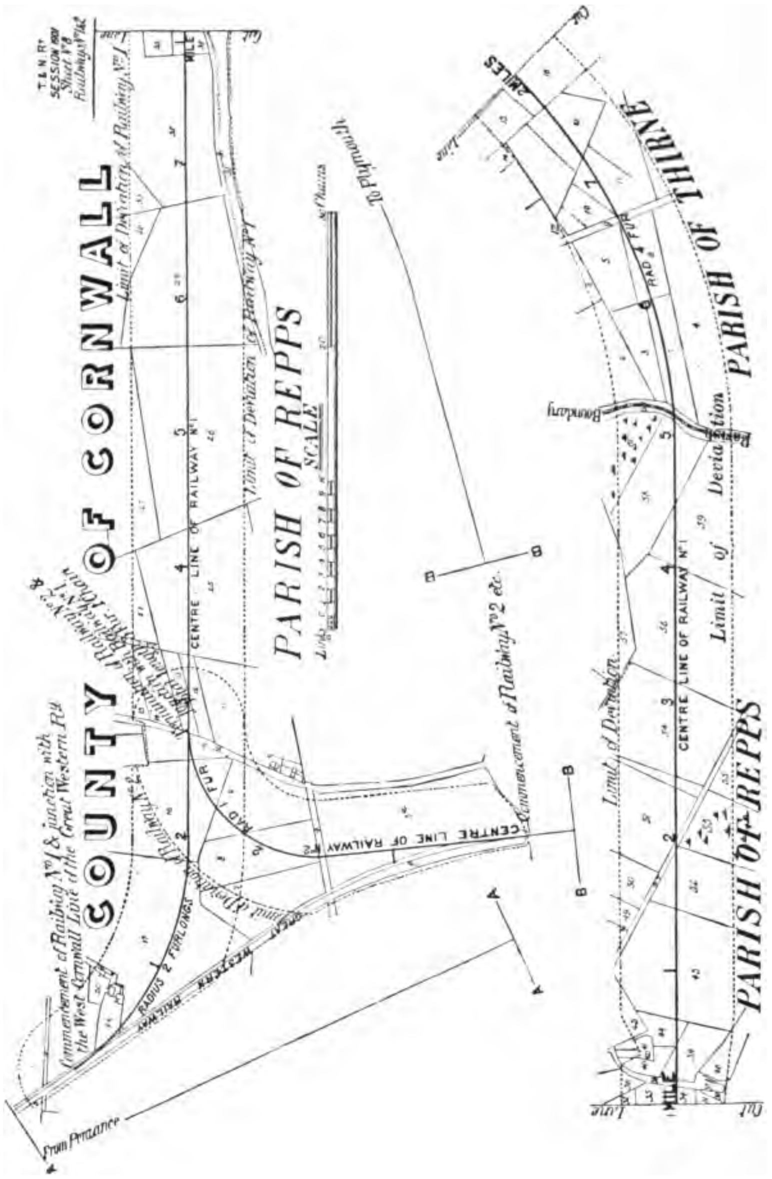

T. & N. Ry
SESSION 1901
Sheet No 8
Railways No 1 & 2
COUNTY OF CORNWALL
Commencement of Railway No 1 & junction with the West Cornwall Line of the Great Western Ry
Limit of Deviation of Railway No 1
CENTRE LINE OF RAILWAY No 1
CENTRE LINE OF RAILWAY No 2
Commencement of Railway No 2 etc.
Limit of Deviation
RADIUS 2 FURLONGS
RAD 1 FUR
RAD 4 FUR
GREAT WESTERN RAILWAY
From Penzance
To Plymouth
PARISH OF REPPS
SCALE
Links
Chains
PARISH OF THIRNE
Boundary
2 MILES
MILE
Line
Limit of Deviation
A
B
1
2
3
4
5
6
7

FIG. 4.

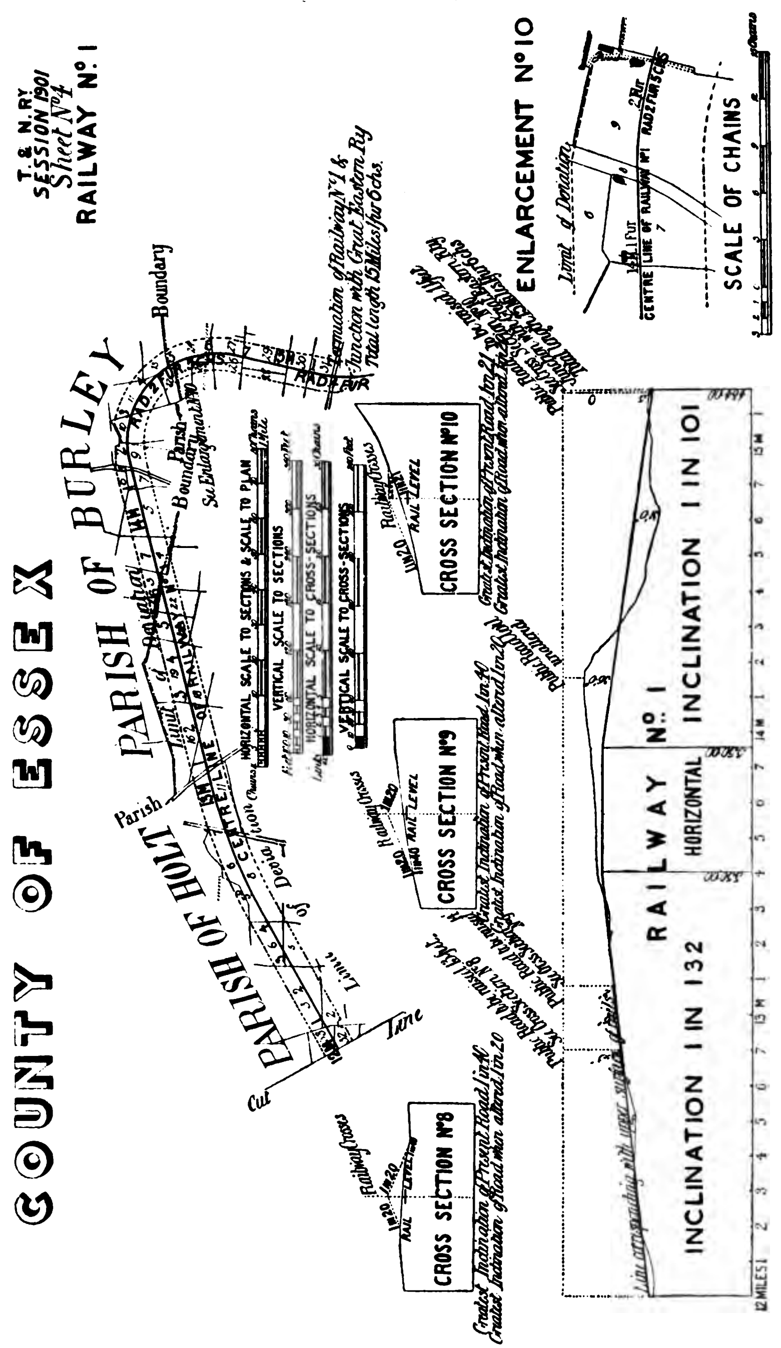

COUNTY OF ESSEX
T. & N. RY.
SESSION 1901
Sheet No 4
RAILWAY No 1
PARISH OF HOLT
PARISH OF BURLEY
Parish
Parish Boundary
Boundary
See Enlargement No 10
Limit of Deviation
CENTRE LINE OF RAILWAY No 1
Cut
Line
Termination of Railway No 1 & Junction with Great Eastern Ry
Total length 15 Miles fur 6 chs.
HORIZONTAL SCALE TO SECTIONS & SCALE TO PLAN
VERTICAL SCALE TO SECTIONS
HORIZONTAL SCALE TO CROSS-SECTIONS
VERTICAL SCALE TO CROSS-SECTIONS
CROSS SECTION No 8
CROSS SECTION No 9
CROSS SECTION No 10
Railway Crosses
RAIL LEVEL
1 in 20
1 in 40
Greatest Inclination of Present Road 1 in 40
Greatest Inclination of Road when altered 1 in 20
Public Road to be raised 13 feet
See Cross Section No 8
Public Road to be lowered
See Cross Section No 9
Public Road to be produced
Public Road to be raised 15 feet
See Cross Section No 10
Greatest Inclination of Present Road 1 in 21
Greatest Inclination of Road when altered 1 in 20
Line corresponding with upper surface of rails
RAILWAY No 1
INCLINATION 1 IN 132
HORIZONTAL
INCLINATION 1 IN 101
12 MILES 1
13 M
14 M
15 M
ENLARGEMENT No 10
Limit of Deviation
CENTRE LINE OF RAILWAY No 1
SCALE OF CHAINS

*FIG. 5.*

The standard scales should next be laid down on paper, an average of the sheets being taken in the case of the ordnance. The scales are generally put on every sheet, but this is not necessary, and they may be put all together on one, as shown in Fig. 6.

From the scale the furlong-points can be marked by means of dividers, taking two or three chains at a time round a curve, or better, by working a strip of tracing-paper with the furlongs on it round the curve by means of a pricker. Sometimes, owing to the shrinkage of the paper, the furlong-points will be found not to correspond exactly with the scale, but a *slight* error in this respect is not of consequence, although the greatest possible care should be taken to ensure accuracy in the first instance.

The first proofs should be compared with the tracings by at least two men separately, and should then be gone carefully over, independently, in case any errors or omissions should have been made in the tracings. The corrections should be shown in red, and a large mark put to call attention to each. After the second proofs have been corrected, the engineer should see that the corrections are marked on the stone, and after printing he should go through the whole book again.

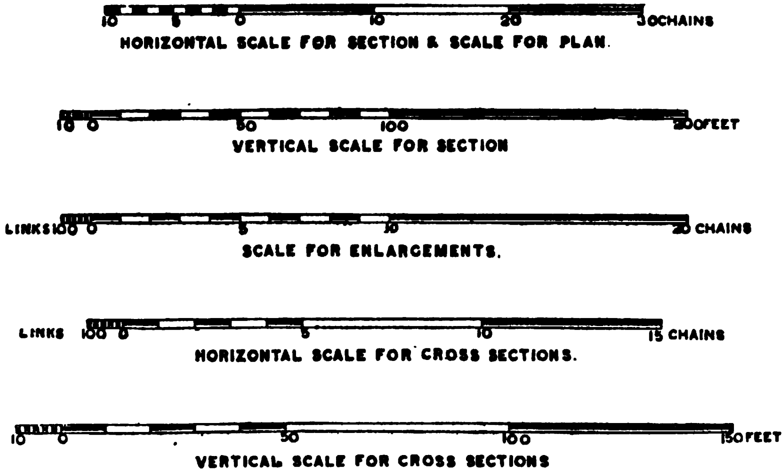

10 5 0 10 20 30 CHAINS
HORIZONTAL SCALE FOR SECTION & SCALE FOR PLAN.
10 0 50 100 200 FEET
VERTICAL SCALE FOR SECTION
LINKS 100 0 5 10 20 CHAINS
SCALE FOR ENLARGEMENTS.
LINKS 100 0 5 10 15 CHAINS
HORIZONTAL SCALE FOR CROSS SECTIONS.
10 0 50 100 150 FEET
VERTICAL SCALE FOR CROSS SECTIONS

*FIG. 6.*

Appendix A gives a list of the things which must be shown on the sheets. It will be found useful in going over the proofs as an aid to memory. Plans for deposit are nearly always done under pressure, and it is only too easy to forget even things that are of the utmost importance, consequently every assistance to the eye and memory should be made use of.

**The Plans in Relation to the Book of Reference.**—It is very desirable that tracings of the plans should *at the earliest possible moment* be sent to the solicitors to enable the Book of Reference to be prepared. These tracings should have the centre line and limits of deviation shown. It must be remembered that the referencers will have to identify the various enclosures, buildings, streams, rivers, roads, canals, railways, tramways, and other physical features drawn upon the plan within the limits of deviation, so that such enclosures, etc., may be correctly described, and the ownership and other interests therein duly recorded in the Book of Reference. For this reason the tracings for the use of the referencer should show the physical features of the ground outside the limits of deviation for a sufficient distance, to enable the referencer to effect the above-mentioned identification with reasonable ease and certainty.

It is the duty of the referencer to put a number (hereafter referred to as the reference number) on the plan for each separate enclosure or other physical feature, and to enter that number in the Book of Reference against the description. The reference numbers should be put on the plans in conjunction with the referencers, and the first proof of the plans should be examined with the reference plan. The engineer should be careful to note that everything shown on his plan is covered by the description assigned to the different reference numbers. When it is clear that the description given in the Book of Reference covers every feature shown on the plan, it is not necessary to put links to outbuildings, etc., but it is better to do so, in order that every feature may bear its own reference number, or be linked with others. Cellars under public streets need not be shown, but, if it is intended to interfere with them, the house they belong to should be marked on the plan and numbered.

**The Section.**—The line having been laid down on the plan, the setting-out tracings, which are required for taking the section, can be prepared. The different distances from fences and other fixed points to the centre line should be measured off in the office, and chord-lines from fence to fence drawn, and the offsets to the curves written on them, so that the setting out on the ground can be done quickly. When the ground is nearly level, it is unnecessary to range the curves, but where it is sidelong, this must be done, and care must be taken to avoid mistakes in the setting out, and especially in not putting the curve on the wrong side of the chord. No allegation can be proved unless the error is more than the vertical limit of deviation, which is 5 feet in the country and 2 feet in a town, either up or down.

The usual mode of proceeding out-of-doors is for one man to do the correcting and setting out and another the levelling, and sometimes, where there are many roads, and those steep ones, it is advisable to have a third to take the cross-sections. To fix the distances, it is the writer's practice to chain through, and, in plotting, to keep moving the scale to agree with the points marked on the section from the plan, as the distance measured on the ground is not likely to agree exactly with that scaled on the plan. In cases where the ground is fairly level, it is not necessary to do this, as the levels can be taken at the fences, and, where necessary, distances can be measured from them, the fences being localized by letters, and the distances by figures, thus:—The man who is setting out may put a paper in a hedge to denote the crossing, and on this he will write (say) **H**, and perhaps measure 3 chains into the field, and put down a lath with **H**3 on it, at the same time marking the hedge on his plan **H**. The leveller will then take sights at these places, and note the letters **H**, **H**3 after them in his book.

In plotting, the datum having been carefully laid down by straining a piece of silk over the paper to insure its being *perfectly straight*, and the furlong-points marked so as to exactly agree with the standard scale, a strip of tracing-paper should be worked along the centre line on the plan in the same way as before described, and the fences, etc., should be marked on it. These can then be transferred to the section by laying the strip on the datum-line, with the corresponding furlong-points over each other, and it will thus exactly correspond with the plan, and, after the plotting, the two should again be compared. The furlong-points can be marked on the plan and the fences taken off on to the strip at one operation. As it is very easy to make a mistake of 10 feet in plotting, it is advisable to go through the work a second time.

The next step, after plotting the section, is the grading. In doing this, to reduce the chance of error to a minimum, it is better to make all gradients as long and to as simple an inclination as possible, such as 1 in 264, or 1 in 66. A gradient of 1 in 101 should, however, be made use of instead of one of 1 in 100, for

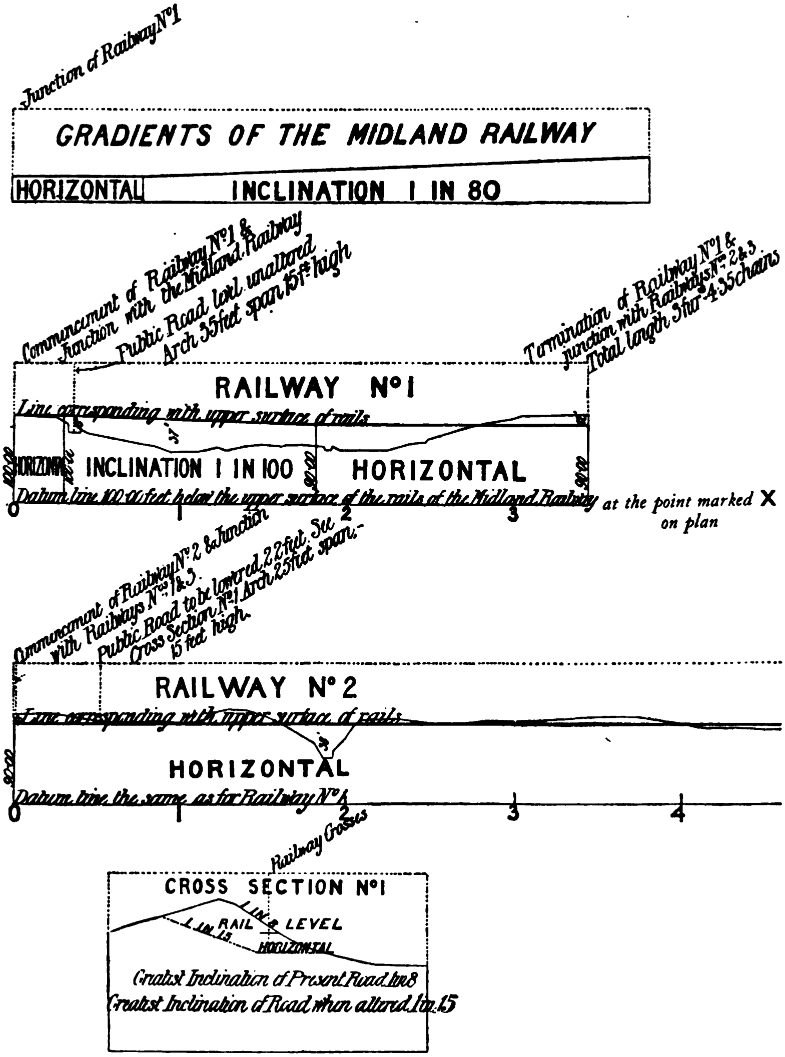

Junction of Railway No. 1
GRADIENTS OF THE MIDLAND RAILWAY
HORIZONTAL
INCLINATION 1 IN 80
Commencement of Railway No. 1 & Junction with the Midland Railway
Public Road level unaltered Arch 35 feet span 15 ft. high
Termination of Railway No. 1 & junction with Railways Nos. 2 & 3. Total length 3 fur. 4·35 chains
RAILWAY No. 1
Line corresponding with upper surface of rails
HORIZONTAL
INCLINATION 1 IN 100
HORIZONTAL
100.00
90.00
Datum line 100.00 feet below the upper surface of the rails of the Midland Railway at the point marked X on plan
0
1
2
3
Commencement of Railway No. 2 & Junction with Railways Nos. 1 & 3.
Public Road to be lowered 2.2 feet. See Cross Section No. 1 Arch 25 feet span. 15 feet high.
RAILWAY No. 2
Line corresponding with upper surface of rails
HORIZONTAL
90.00
Datum line the same as for Railway No. 1
0
1
2
3
4
Railway Crosses
CROSS SECTION No. 1
1 in 8
1 in 15
RAIL LEVEL
HORIZONTAL
Greatest Inclination of Present Road 1 in 8
Greatest Inclination of Road when altered 1 in 15

FIG. 7.

in constructing the line it may be altered to 1 in 85, whereas the 1 in 100 can only be altered to 1 in 94·5, except by the permission of the Board of Trade, which, however, is not difficult to obtain in this case; moreover, a clause is generally put in the Order to the effect that any horizontal portion or gradient may be altered to some fixed ruling gradient, such as to 1 in 40.

It is a little difficult to find out what the exact gradients of an existing line of railway are, as they sometimes alter at every chain, but it is not necessary to show every small change. It is usual to show an existing railway by a solid line, and one authorized by a dotted line.

Appendix A shows the other points of importance in preparing the section, and this should be before the engineer when he is checking the proofs.

In Fig. 7 is given part of a section sheet which will, it is hoped, make all this quite clear.

Appendix B gives a list of the various scales to which the ordnance plans are prepared.

Appendix C is a copy of the principle Board of Trade rules (which are nearly the same as the standing orders) affecting the engineer as published in 1898. As these are subject to alteration, corrections must be made from time to time.

The following is a list of the complete sets of plans and sections which are required for deposit:—

For the Board of Trade (2 sets).

For the Clerk of the Council of each county.

For the Clerk of the Council of each district, parish, and borough.

For the Board of Trade—Fisheries and Harbour Department.

For the Conservators of each river.

The deposit with the Harbour Department of the Board of Trade is only necessary when tidal waters are touched. It must have the words "Tidal Waters" written on it, and these must be coloured blue; also the span and headway of the nearest bridges, above and below, over any tidal river, which is to be crossed by a bridge, must be given. So much of, and only so much of, the plans as relates to each parish and urban sanitary authority must be deposited with the clerk of the parish or authority, and so much as relates to any church or churchyard, which is affected, with the Secretary of the Home Office, but it is not necessary to cut off the parts of the sheets that do not apply.

All the deposits must have a copy of the inch-scale ordnance with all the lines and their mile points shown on them.

The lines must be shown on the ordnance in red, and it may be noted that the 1-inch ordnance need not necessarily be used as in the case of a Bill before Parliament, but a larger scale ordnance may be employed if desired.

**Tramways.**—Power to make a tramway can be obtained by an Act, or a provisional order from the Board of Trade.

The plans for a tramway have to be prepared in much the same way as for a light railway. They must show if the tramway is to be laid along the centre of the road, and if not, on what side and how far from the imaginary centre line of the road, and where the spaces of less than 9 feet 6 inches or 10 feet 6 inches, as explained below, occur; here the nearest rail should be shown by a thick dotted line, and the width of the road between the kerbstones must also be given. Each double portion, even if only a passing-place, should be shown by two lines. The length of each double and single portion and the total length of such double and single portions, respectively, must be given. The distances between the double portions must be given, a clear space between the vehicles of 15 inches being allowed for. The section should be on the same sheet as the plan. The gradients of the roads must be given, but not the heights above datum. In other respects both plan and section should be as for a railway, except that the radii of the curves need not be given. The crossing of railways, tramways, rivers, and canals must be shown, and, in the first two cases, it must be specified if they are to be crossed over, under, or on the level, but no cross-sections are required. All tidal waters must be coloured blue.

The plan and section in Fig. 8 will illustrate this.

Notices must be posted in the streets where the tramway is to be laid for 14 consecutive days before November 30, and it must be stated in the advertisement, where for a length of more than 30 feet a distance will exist between the kerb and nearest rail of less than 9 feet 6 inches, or of 10 feet 6 inches, if ordinary railway carriages and waggons are to be used.

The plans must be accompanied by the 6-inch ordnance with the tramways marked on it in red, and by a diagram, as in Fig. 9, to a scale of not less than 2 inches to a mile.

The following note should be on each sheet:—

NOTE.—Each of the intended tramways shown upon the plans will be laid to a gauge of 4 feet 8½ inches.

The imaginary centre line of the street or road is represented

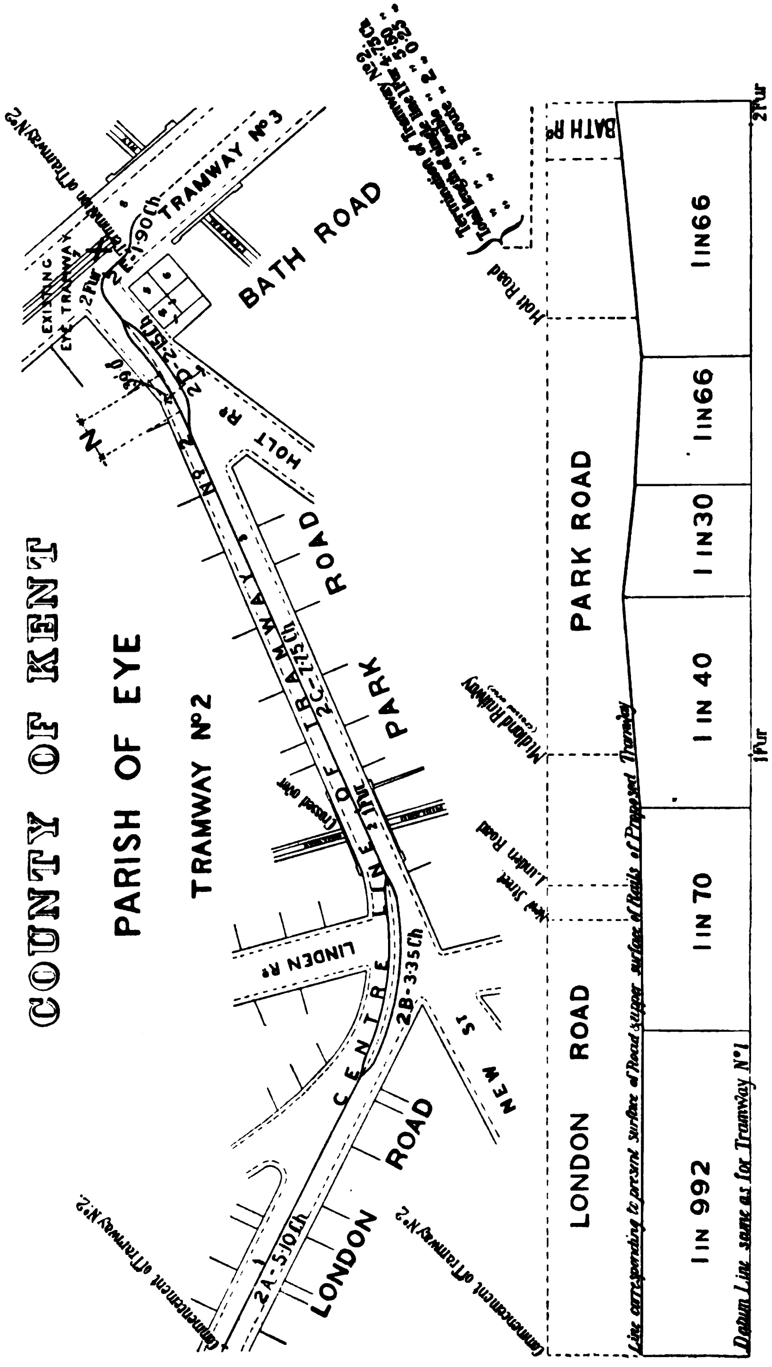
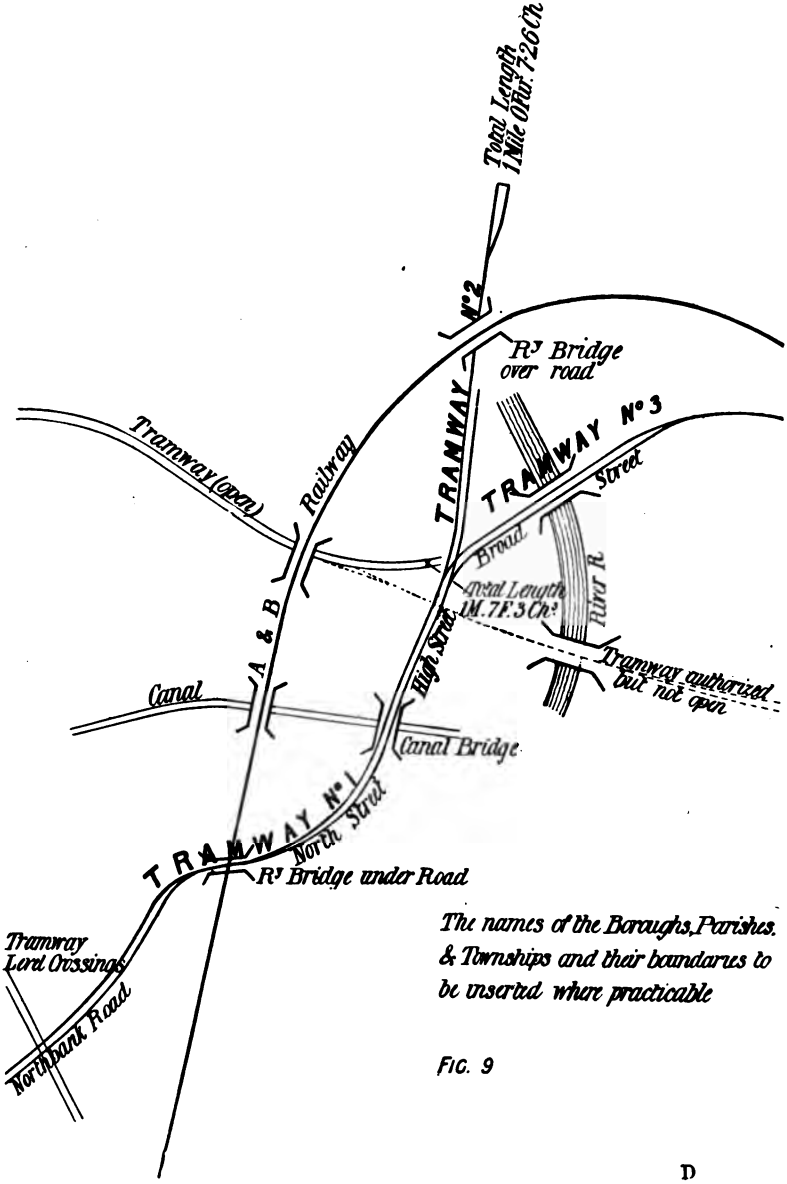

COUNTY OF KENT
PARISH OF EYE
TRAMWAY No 2
EXISTING TRAMWAY
EYE
TRAMWAY No 3
BATH ROAD
2E-1·90Ch
2 Fur
2D-2·15Ch
HOLT Rd
TRAMWAY No 2
30 ft
N
PARK ROAD
CENTRE LINE OF TRAMWAY
2C-2·75Ch
1 Fur
(crossed over)
LINDEN Rd
2B-3·35Ch
NEW St
LONDON ROAD
2A-5·10Ch
Commencement of Tramway No 2
Commencement of Tramway No 2
Termination of Tramway No 2
Termination of Tramway No 2·75Ch
Total Length of Single Line 4·75Ch
" " Double " 5·85 "
" Route " 2 " 0·23 "
BATH Rd
Holt Road
PARK ROAD
Midland Railway (crossed over)
Linden Road
New Street
LONDON ROAD
1 IN 66
1 IN 66
1 IN 30
1 IN 40
1 IN 70
1 IN 992
2 Fur
1 Fur
Line corresponding to present surface of Road & upper surface of Rails of Proposed Tramway
Datum Line same as for Tramway No 1

FIG. 8.

# DIAGRAM OF PROPOSED TRAMWAYS.

*Scale, not less than 2 Inches to a Mile*



The names of the Boroughs, Parishes & Townships and their boundaries to be inserted where practicable

FIG. 9

by a dotted line thus - - - - - - - - - - and the centre line of each tramway thus ————.

Where the dotted line is not shown the centre line of the tramway will coincide with the imaginary centre line of the street or road.

Where double lines are shown thus ≡≡≡≡≡≡≡≡≡≡ the centre lines of the tramways will be on each side of and at a distance of 5 feet from the imaginary centre line of the street or road, except where otherwise figured on the plan.

Where it is proposed to lay any tramway so that for a distance of 30 feet or upwards a less space than 10 feet 6 inches shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway, such distance is indicated on the plan thus

N
✱ - - - - - - - - - - ✱, on the side or sides of the street or road where such less space intervenes.

This note is also sometimes necessary—

Note.—At the point X the centre line of the tramway will be laid 10 feet 6 inches south of the imaginary centre line of the road.

The works must be commenced within a year and completed within two years or the powers lapse.

**Subways.**—These are treated like railways, but their height and width must be marked and a description given as to how access is to be provided, the following note being generally written on each sheet:—

Note.—The up and down lines of the proposed railway are intended to be placed in separate tunnels, each circular in section and 12 feet internal diameter, with enlargements at the stations, and it is proposed to afford access to the railway by means of stairs and lifts or inclines.

It is not intended to alter the surface level of any street, road, or tramway.

# CHAPTER III.

## *WORKING PLAN AND SECTION.*

Deviations—Staking out—Table of angles for curves—Working section—Cross-sections—Half-width book—Plan—Areas of land—Resetting out—Road approaches—Headway for bridges.

IT has already been stated that the centre line may be altered to any position within the "Limits of Deviation," if no property is taken that has not been scheduled; hence, to secure the best line, it is necessary to go carefully over the ground, taking trial levels and cross-sections where necessary, and plotting longitudinal sections from them.

In making any variation from the line shown on the deposited plans, it must be remembered—

That the rule "that no curve of over 40-chains radius may be made sharper than 40-chains radius" does not apply, but that a curve of a certain radius, as fixed in the order, may be introduced anywhere.

That the ruling gradient as fixed in the order may be introduced anywhere, and that the engineer is not tied by the rules.

(1) "That gradients of over 1 in 100 may not be made more than 10 feet per mile steeper as in Appendix F."

(2) "That gradients of 1 in 100 and under may not be made more than 3 feet per mile steeper as in Appendix F."

(3) That the levels of the rails may not be raised or lowered more than 5 feet in the country and 2 feet in land continuously built upon.

That tunnels and viaducts must be made of the full length shown, unless, in the case of tunnels, permission be obtained for shortening or doing away with them. Tunnels may, however, be substituted for cuttings and viaducts for embankments without its being necessary to ask any one's permission.

That no deviation into a navigable river may be made without special leave from the Board of Trade, even if the limits of deviation provide for it.

The sharpest curve is usually put at 9-chains radius and the steepest gradient at 1 in 50. The level of the rails may not be altered more than 5 feet at a public road, nor more than 2 feet at a town or village street, and in no case must an embankment be made more than 10 feet higher than shown, except by the consent of all concerned in each case.

It must also be remembered in laying down the centre line that the authorized line is not necessarily the line shown on the deposited plans, as special clauses may have been introduced into the order to fix it in some other position, and roads, etc., may have been required to be dealt with in a different manner from that shown on the plans.

**Staking Out.**—The assistant who is charged with the duty of setting out the line must be provided with a plan showing its intended course with the tangent lines, produced if necessary, marked thereon. To save time in the field, he should scale all the distances from the tangents to the cross-hedges, etc., in the office, and write them in pencil on the plan.

The operations in staking out can be best understood by referring to Fig. 10.

We will assume that the straight line **AB** has been staked out nearly up to the point **B**, and that it is now wished to set out the curve between **B** and **C** and the straight line **CD**.

Leaving his theodolite still fixed on the line **AB** in charge of a man, he will proceed to pick up the line **CD** by measuring from the cross-hedges, etc., to it, so establishing a number of points on the line. Owing to inaccuracies in the plan, he will generally find that the poles he has put in at these points are not exactly in a straight line, and it will be necessary to alter them somewhat. Going back to the theodolite, he will then produce the line **AB**, which he has been staking out, to the intersection point **X**. This point will, of course, be exactly in the line **AB**, and nearly, but not necessarily quite, in the line **CD**, as picked up from the cross-hedges. He will then take up the instrument, set it up at **X**, and measure the angle **AXD**, from which, the radius being known, the tangent points **B** and **C**, the length of the curve, and the point **V** on it, can be found. With the theodolite still at **X**, the three points **B**, **C**, and **V** can often be put in, and the line **XCD** is *now* fixed, although it will not perhaps exactly agree with the line as first picked up. The theodolite must next be moved to the tangent point **B**, and the remaining chain pegs on the straight line **AB** having been put in by means of it up to less than a chain from this point, the distance from the latter to the first chain point on the curve can be measured, and from it the proper angle calculated. This distance is called the "first odd distance," the distance from the chain-peg to the point **V**, which is at the centre of the curve, the "second odd distance," and that from the chain-peg to the tangent point **C**, the "third odd distance."

In some cases it is possible to see the whole length of the curve, but it is generally necessary to move the theodolite when a portion has been staked out, and set it up again. The curve must pass exactly through the points **V** and **C**, and the distances to these points must be as calculated, or it will be clear that an error has been made.

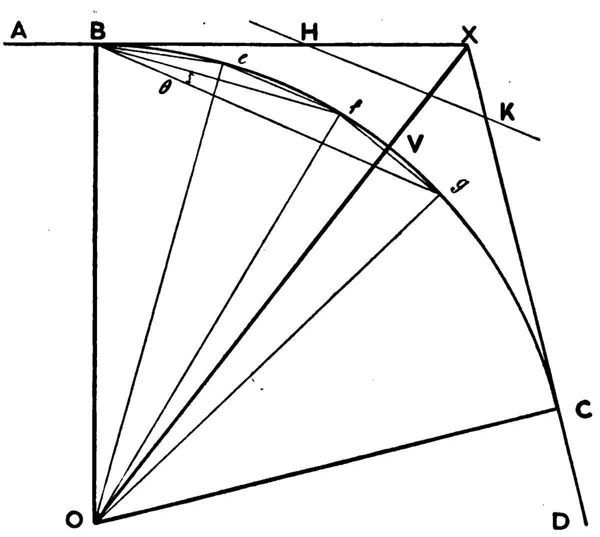


*FIG. 10.*

Certain difficulties such as obstructions and impossible sites for the instrument will occur, and the engineer will have to use some ingenuity in getting over them, but if he considers the diagram in Fig. 10 he should be able to treat any case that may arise.

Let O be the centre of the circle, and let $a$ be put for the angle of intersection BXC.

Then, by the principles of trigonometry, we have—

$$\cot\frac{a}{2} = \frac{BX}{OB} = \frac{T}{R}. \qquad \text{Hence} \qquad T = R\cot\frac{a}{2}$$

$$\operatorname{cosec}\frac{a}{2} = \frac{OX}{OB} = \frac{R+V}{R}. \qquad \text{,,} \qquad V = R\operatorname{cosec}\frac{a}{2} - R$$

$$\frac{\text{chord BVC}}{2\pi R} = \frac{\text{angle BOC}}{360^\circ} = \frac{180^\circ - a}{360^\circ}. \qquad \text{,, chord BVC} = \frac{\pi R(180^\circ - a)}{180^\circ}$$

$$= \frac{R}{57{\cdot}3}(180^\circ - a)$$

$a$ in this last case being expressed in degrees and *decimals,* not minutes.

If the theodolite cannot be set up at X, the angles at any points HK in the tangents may be taken, and the distance HK measured. Then we have—

$$a = 180^\circ - XHK - XKH$$

$$\frac{HX}{HK} = \frac{\sin XKH}{\sin a}. \qquad \text{Hence } BH = BX - HX = T - HK\frac{\sin XKH}{\sin a}$$

$$\text{and so } CK = \qquad T - HK\frac{\sin KHX}{\sin a}$$

The angle at the circumference $\theta$, subtended by any chord C, is half that at the centre, so that we have—

$$\frac{2\theta}{360^\circ} = \frac{C}{2\pi r}. \qquad \text{Hence } \theta = 90\frac{C}{\pi r} = \frac{C}{r}28{\cdot}65$$

If B$e$ and $ef$ are equal, B$f$ is at right angles to $e$O, and consequently—

$$\text{The angle } XBe = 90^\circ - eBO = 90^\circ - BeO = eBf$$

If B$e$, $ef$, and $fg$ are equal—

$$\text{The angle } efg = 2efO = efO + feO = 180^\circ - eOf = 180^\circ - 2eBf$$

The following example will make the method of setting out a little more clear:—

Let $a = 130^\circ\ 10'$, and $R = 30$ chains;

$$\begin{aligned}
\text{then } \mathrm{T} &= \mathrm{R} \cot \frac{a}{2} = 30 \cot 65^\circ\, 5' \\
\log \mathrm{T} &= \mathrm{L}\ 30 + \log (\cot 65^\circ\, 5') - 10 \\
&= 1{\cdot}4771213 + 9{\cdot}6670214 - 10 \\
&= 1{\cdot}1441427 \\
\textit{i.e.}\ \mathrm{T} &= 13{\cdot}94 \text{ chains.} \\
\text{Again } \mathrm{V} &= \mathrm{R} \operatorname{cosec} \frac{a}{2} - \mathrm{R} \\
\text{and } \log \left(\mathrm{R} \operatorname{cosec} \frac{a}{2}\right) &= \log 30 + \mathrm{L} \operatorname{cosec} 65^\circ\, 5' - 10 \\
&= 1{\cdot}4771213 + 10{\cdot}0424303 - 10 \\
&= 1{\cdot}5195516 \\
\therefore \mathrm{R} \operatorname{cosec} \frac{a}{2} &= 33{\cdot}08 \\
\text{and so } \mathrm{V} &= 33{\cdot}08 - 30{\cdot}00 \\
&= 3{\cdot}08 \text{ chains}
\end{aligned}$$

Next—

$$\begin{aligned}
\text{Length of the curve} &= \frac{30}{57{\cdot}3}(180^\circ - 130{\cdot}17^\circ) = \frac{4983}{191} \\
&= 26{\cdot}09 \text{ chains} \\
\text{The angle for 1 chain} &= \tfrac{1}{30} 28{\cdot}65^\circ \\
&= \tfrac{60}{30} 28{\cdot}65' \\
&= 57{\cdot}3' \\
\text{The angle for } 33\tfrac{1}{3} \text{ links} &= \tfrac{1}{3}\ 57{\cdot}3' = 19{\cdot}1'
\end{aligned}$$

The following particulars required for each curve should be neatly entered in the engineers' field-book :—

| | | | |
|---|---|---|---|
| Angle of intersection | 159° 14′ | Angle for 1 chain . . . . | 0° 29′ |
| Radius . . . . . . | 60·00 chains | Angle for 10 chains . . . . | 4° 46′ |
| Length of tangent . . | 10·99 „ | Curve begins at 13 miles | 71·31 chains |
| „ secant . . | 1·00 „ | Secant point „ 14 „ | 2·18 „ |
| „ curve . . | 21·75 „ | Curve ends „ 14 „ | 13·06 „ |
| First odd distance . . | 0·69 „ | Angle for first odd distance . . | 20′ |
| Second „ . . | 0·18 „ | „ second „ . . | 5′ |
| Third „ . . | 0·06 „ | „ third „ . . | 2′ |

The angle for 2 chains is twice that for 1, and for 25 links one-fourth, and so on.

The angle for a curve of 10-chains radius is twice that for one of 20-chains radius.

The following are the angles for some of the most common curves:—

| Radius. | Angle for 1 chain. | | Angle for 10 chains. | | Angle for 100 feet. | |
|---|---|---|---|---|---|---|
| | ° | ′ | ° | ′ | ° | ′ |
| 10 chains or 660 feet . . . . | 2 | 52 | 28 | 39 | 4 | 21 |
| 20 „ 1320 „ . . . . | 1 | 26 | 14 | 19 | 2 | 10 |
| 30 „ 1980 „ . . . . | 0 | 57 | 9 | 33 | 1 | 27 |
| 40 „ 2640 „ . . . . | 0 | 43 | 7 | 10 | 1 | 5 |
| 60 „ 3960 „ . . . . | 0 | 29 | 4 | 46 | 0 | 44 |
| 80 „ 5280 „ . . . . | 0 | 21 | 3 | 35 | 0 | 32 |
| 9·55 „ 630 „ . . . . | 3 | 00 | 30 | 0 | 4 | 33 |
| 14·32 „ 945 „ . . . . | 2 | 00 | 20 | 0 | 3 | 2 |
| 28·65 „ 1890 „ . . . . | 1 | 00 | 10 | 0 | 1 | 31 |
| 14·47 „ 955 „ . . . . | 1 | 59 | 19 | 48 | 3 | 0 |
| 21·70 „ 1432 „ . . . . | 1 | 19 | 13 | 12 | 2 | 0 |
| 43·41 „ 2865 „ . . . . | 0 | 40 | 6 | 36 | 1 | 0 |

After the line has been staked out, sufficient dimensions should be taken to enable it to be laid down accurately on the survey, of which it is, so far as it goes, a perfect check. When the 25-inch ordnance exists, it is usually made use of for the plan, and when a survey has to be made, this is commonly plotted to a scale of 3 chains to an inch, which is about, but not quite, the same as the 25-inch ordnance scale.

Errors will occur through the instrument not being in adjustment or inaccurately set up, but they more often come from bad chaining. Great accuracy can generally be secured by using a steel band in place of the chain.

**The Section.**—After the line has been staked out, the section is taken, and the level of *every* peg, road, etc., should be carefully checked, and cross-sections taken at *every* chain, even when the ground is apparently level.

If a scale of 3 chains to an inch has been used for the plan, it will be convenient to use 30 feet to an inch as the vertical scale for the section, and 30 feet to an inch also for both the vertical and horizontal scales of the cross-sections, for although this is rather small for the cross-sections, it saves a chance of error.

Fig. 11 illustrates a portion of a working section. The earthwork quantities signify the contents of the cutting from half a chain before to half a chain after the chain point at which they

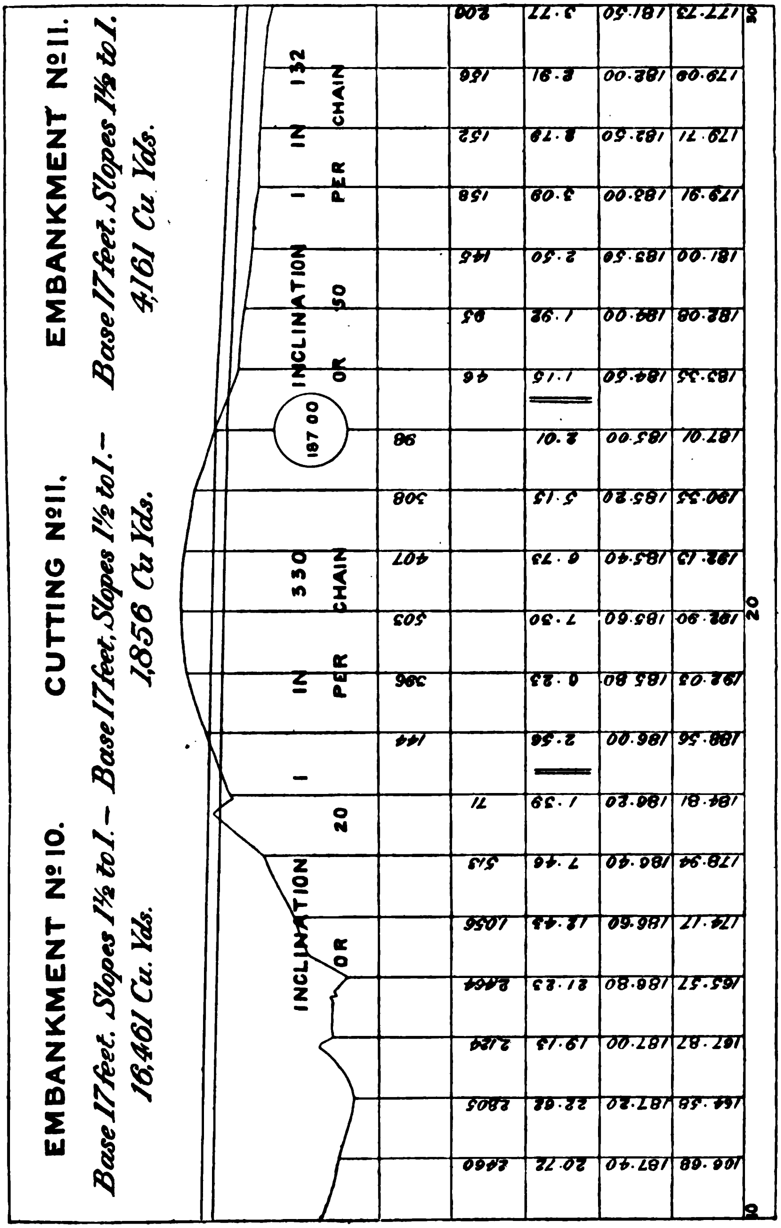

EMBANKMENT No 10.
Base 17 feet. Slopes 1½ to 1.- 16,461 Cu. Yds.
CUTTING No 11.
Base 17 feet, Slopes 1½ to 1.- 1856 Cu Yds.
EMBANKMENT No 11.
Base 17 feet. Slopes 1½ to 1. 4,161 Cu Yds.
INCLINATION 1 IN 330 OR 20 PER CHAIN
INCLINATION 1 IN 132 OR 50 PER CHAIN
187 00
10
20
30
2460 20·72 187·40 166·68
2805 22·62 187·20 164·58
2124 19·13 187·00 167·87
2464 21·23 186·80 165·57
1056 12·43 186·60 174·17
513 7·46 186·40 178·94
71 1·39 186·20 184·81
144 2·56 186·00 188·56
396 6·23 185·80 192·03
503 7·30 185·60 192·90
407 6·73 185·40 192·13
308 5·15 185·20 190·35
98 2·01 185·00 187·01
46 1·15 184·60 183·35
95 1·92 184·00 182·08
145 2·50 183·50 181·00
158 3·09 183·00 179·91
152 3·79 182·50 178·71
156 2·91 182·00 179·09
208 3·77 181·50 177·73

FIG. 11.

are written. In the first column are given the heights of the pegs above datum, in the next the heights of formation above this level, and in the third, the difference between these, *i.e.* the depths of cutting or bank.

If possible the simple gradients given in Appendix G should be made use of, as they save time and consequent risk of error, and, besides, look more businesslike.

Fig. 12 illustrates a cross-section. The minimum formation width for an ordinary railway should be 28 feet for a double line and 17 feet for a single line, the lines being assumed to be 11 feet centre to centre, although as a matter of fact they are a little more. The ratio of the slopes as shown is 1½ to 1, and a cess of 12 feet is given for the ditch and quick. In the case of cuttings the slopes vary from ½ to 1 to as much as 3 to 1, and in the case of embankments from 1⅜ to 1 to 3 or 4 to 1; but as a general rule land is taken for 1½ to 1 slopes in each case and for a double line.

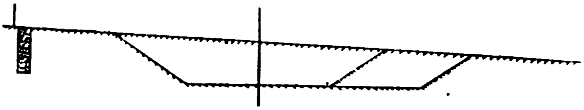


*FIG. 12.*

For light lines, where the ballast under the sleepers is only 6 inches in thickness, the formation width may be reduced to 14 or even to 12 feet, and the cess to perhaps 3 feet.

**The Plan.**—The centre line having been laid down on the plan and all the chain points marked, the fence lines are drawn thereon by using a "half-width book" as indicated below.

**Formation, 28 feet; Slopes, 1½ to 1; Cess, 12 feet.**

| Left half width. | | Height of bank. | | Chainage. | | Depth of cutting. | | Right half width. | |
|---|---|---|---|---|---|---|---|---|---|
| feet | in. | feet | in. | miles | chains | feet | in. | feet | in. |
| 28 | 6 | | | 8 | 20 | 7 | 3 | 45 | 6 |
| 27 | 0 | | | 8 | 19 | 6 | 2 | 43 | 6 |
| 28 | 3 | | | 8 | 18 | 2 | 5 | 37 | 3 |
| 27 | 0 | 1 | 4 | 8 | 17 | | | 31 | 0 |
| 34 | 6 | 7 | 5 | 8 | 16 | | | 40 | 0 |
| 42 | 0 | 12 | 4 | 8 | 15 | | | 47 | 0 |
| 55 | 6 | 21 | 2 | 8 | 14 | | | 60 | 0 |
| 53 | 0 | 19 | 1 | 8 | 13 | | | 56 | 0 |
| 59 | 0 | 22 | 6 | 8 | 12 | | | 61 | 0 |
| 55 | 0 | 20 | 7 | 8 | 11 | | | 59 | 0 |
| 49 | 6 | 18 | 0 | 8 | 10 | | | 55 | 6 |

This is used first for transferring the heights of cutting and bank from the main to the cross-sections, and secondly, for taking the half widths from these and marking them on the plan, and again, in setting out the fencing on the ground.

When these widths have been marked on the plan, and when the extra land required for the road divisions, etc., has also been marked thereon, the areas of the land required may be calculated. In doing this, when the ordnance plans have been made use of, allowance must be made for the hedges; for the lines on the ordnance do not represent the divisions of property, but the centres of the hedges. The true division is generally 4 feet from the centre of the hedge and also generally on the ditch side of it, as in Fig. 13. This, however, must be ascertained by inquiry on the spot.

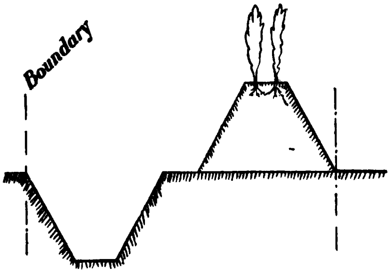


*FIG. 13.*

The areas should be taken out by two men quite independently, and the squaring up checked in each case. If there is but a slight error the larger area should be taken.

In Fig. 14 part of a contract plan is given to illustrate this.

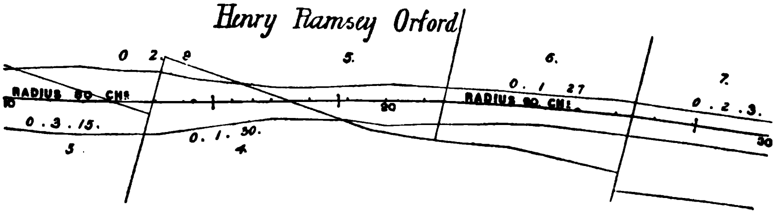


*FIG. 14.*

When the line is being constructed, it is advisable as soon as the fencing has been erected to mark the chain points on it, and, except in the case of high banks, to *accurately* measure the distances from the centre pegs to the fences on *each* side; for these will generally be found to be a little different from those used in setting out, and errors of a few inches will often give a good deal of trouble in picking up the centre line for the bridges and permanent way. It will also be found useful at the ends of each cutting to put in pegs, giving the rail-level at the chain point opposite them, to act as bench marks.

**Road Approaches.**—When a road is 20 feet wide between the fences, a formation width of 25 feet at a foot below its surface should be given in the case of a bank. In the case of a cutting 20 feet is sufficient.

Where a road is on a steep incline, a radius of not less than 3 chains should be given, to enable a team of four horses to pull straight at their load. On the level a sharp turn is not objectionable so long as the drivers of approaching vehicles can see each other.

The span, headway, and inclination of the roadway are specified in the deposited plans and in the order, but for public roads it may be stated generally that where the width of the existing roadway is not more than 20 feet within 50 yards of the point of crossing, a span of 20 feet must be given, and where more, a span equal to the width of the road, but not over 25 feet. The headway for a width of 10 feet should be 15 feet, the springing of the arch 12 feet high, and the greatest inclination of the roadway 1 in 20, or not greater than the existing inclination if this is steeper than 1 in 20. If a 20-foot road is afterwards widened, the bridge must also be widened, unless the width is covered by the order.

For occupation roads a span of 12 feet, headway of 14 feet for a width of 9 feet, and approaches at 1 in 16 are sufficient.

In towns it is usual to make the bridge the full width of the road.

# CHAPTER IV.

## *FENCING.*

**Road approaches—Post and rail—Wire—Cattle-pens—Quicks—Dry stone walls—Pale and space—Unclimbable iron—Close boarding—Brick walls—Old sleepers—Field gates—Large sliding gates—Cattle guards—Setting out fencing from half-width book and with the level—Occupation roads—Notice-posts.**

LIGHT railways, like all others in this country, nearly always require fencing to prevent cattle from straying on the line, and, in thickly populated districts, to guard against trespass. Passenger platforms may have to be shut off to facilitate the collection of tickets, and the sides of road approaches must also be protected.

For each of these objects a different kind of fence is required. In the first case, it is only necessary to prevent the intrusion of cattle, lambs, pigs, and the like; but something which is unclimbable must be provided in order to stop trespass and to properly enclose the platforms, while for the safety of vehicles on road approaches, all that is required is a mere guard.

**Arris Rail Fence.**—This, when wrought and painted, gives a good finish to a road approach. It should consist of a square rail about 4 inches × 4 inches, laid with the diagonals horizontal and vertical, resting on 6-inch × 3½-inch posts, 9 feet apart and 7 feet long, the top of the rail being 3 feet 6 inches above the level of the road. Two 3¼-inch × 1½-inch additional rails should be morticed into the posts, and the top rail secured to the post by means of a strip of No. 16 B.W.G. hoop iron, 1¼ inches wide and 18 inches long.

**Post and Rail.**—This is the most commonly used fence, both for approaches and boundaries. The posts should be 6 inches × 3 inches in size and 7 feet 8 inches long; they should be placed 9 feet apart and 3 feet in the ground, and have a piece of 1¼-inch No. 16 B.W.G. hoop iron nailed round the top. The rails, which are usually 18 feet long and five in number, should not be less than 4 inches × 1½ inches, and the spaces between them not more than 5 inches to 2 feet 3 inches above the ground, nor more than 10 inches apart above this. Instead of being morticed into them, the rails are now usually fixed to the posts by nails which should pass right through both and be clenched on the far side, the rails being placed on the side of the post which is furthest from the railway or, in the case of a raised approach, on the road-side, the top of the top rail being set at 4 feet 6 inches above the ground. A 3-inch × 3-inch intermediate stake or "prick-post," 6 feet long, is necessary between the main posts.

**Post and Wire.**—For this the posts and prick-posts must be of the same dimensions, and be spaced as before. The wires, of which there should be nine, must be of about No. 6 black-rolled or 7-stranded galvanized iron or steel; those up to 2 feet 6 inches above the ground being 5 inches apart and the rest 8 inches apart, so that the top one may be 4 feet 6 inches above the surface. When not against a road, two or three of the wires are generally made of two-ply galvanized wire with four-point barbs, 6 inches apart, weighing about 25 lbs. per 100 yards each, including the barbs and the two wires. 6-inch × 4-inch straining-posts with rakers the same size should be placed 5 chains apart, and the wires should be strained by ⅝-inch eyebolts 18 inches long.

**Cattle-pens.**—For cattle-pens, layers, and walks some additional strength is required. What is shown in Figs. 15 and 16 will be found to be suitable. If the cattle-walk is shut off from the road it must be paved, so it is usual not to hang a gate at the end of it.

**Hedges.**—It rarely happens that a hedge grows well enough to make a perfect barrier, and if it does it has frequently to be grubbed just as it is perfect on account of alterations, widenings, or slips, so that it would seem to be a waste of money to plant one at all. However, when the hedge does grow well it makes a perfect barrier, and, especially if a barbed wire is put in it, effectually prevents trespass. Before planting, the site should be trenched two spits or 18 inches deep, and soil added if the ground is bad. The quicks should be placed in two rows, 9 inches apart each way, and planted between October and February.

**Dry Stone Walls.**—These are sometimes employed where suitable stone is to be obtained, but soft perishable stone is, of course, useless. The walls should be founded a foot below the surface, and be 14 inches wide at the top and 24 inches at the bottom, the height being 4 feet 6 inches. Flat stones set on edge in mortar make the best coping.

**Pale and Space.**—This is very suitable for passenger platforms, and, when there used, is generally made about 4 feet 6 inches high. The posts should be 6 inches × 4 inches in size, 6 feet apart, and 7 feet 6 inches long, with 3 feet in the solid ground. The rails, which should be out of 3½ inches × 3½ inches, cut diagonally, must be mortised into the posts, and the pales, for which 3 inches × 1 inch is a good size, must be pointed at the top, and not be more than 2½ inches apart. A very neat appearance is given if 3-inch × 3-inch × ⅜-inch angle irons, fitting into cast-iron shoes on the posts, are substituted for the 3½-inch × 3½-inch wooden rails, the pales being attached to them by rivets. For boundaries in towns the fence ought to be 7 feet high, when the dimensions should be increased in proportion. It is not very suitable for this purpose, however, as the pales are liable to be torn off and stolen, and when near a canal long lengths may be pulled down by barges being made fast to it.

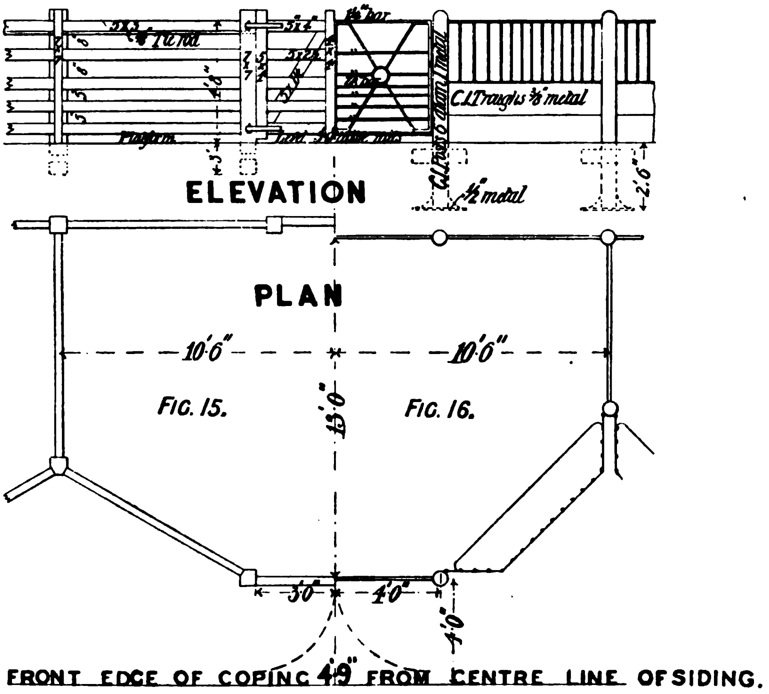


FIG. 15. FIG. 16.

**Iron Pale and Space.**—A very good unclimbable iron fence may be formed of two 2-inch × ½-inch rails, fixed by ⅝-inch bolts to

2½-inch × ¾-inch × ¼-inch **I I** posts, 6 feet apart and 6 feet high, with ¾-inch square vertical bars, placed diagonally on plan, 4 inches apart, and spiked at the top, the **I I** posts to be bent and twisted below the ground-line and riveted to horizontal base-plates 18 to 24 inches square. For platforms, when 4 feet 6 inches is all the height that is required, all these dimensions may be a little reduced.

**Close Boarding.**—The posts and rails for this should be similar to those for the pale and space fence, but a little stiffer, as the boarding ought to be 7 feet high. The posts may be 7 inches × 5 inches, 10 feet apart and 3 feet 6 inches in the ground, the rails out of 4 inches × 4 inches and three in number, and the boarding, which ought to be 1⅛ inches or 1¼ inches thick, should be placed vertically, and secured on the top by a capping surmounted by a number of 2-inch spikes 1½ inches apart, and at the bottom by a horizontal board, which must be firmly fixed to the posts, to prevent the boards being pulled off. This kind of fence has often to be used when the railway is near a road—as a screen.

**Brick Walls.**—These should be at least 7 feet high, and be surmounted by a coping of broken glass bottles or spikes. They must be at least 14 inches thick, and have 9-inch counterforts 2 feet wide, 10 feet apart, with foundations 2 feet below the ground-line. The appearance may be improved by panelling and plinths.

**Old Sleepers.**—These are sometimes employed, and when in a fair state of preservation are useful in many situations, as on a canal bank. Being 9 feet long, they may be placed 2 feet 6 inches in the ground, and the 6 feet 6 inches left above the ground will be sufficient if the top is covered with spikes.

**Gates.**—A clear space of 10 feet between the posts should be given for ordinary field gates and of 13 or 14 feet for level crossings. For the former, the following dimensions will be found satisfactory:—

Hanging posts 10 inches × 10 inches, clapping posts 7 inches × 7 inches, hanging styles 7 inches × 3 inches, clapping styles 4 inches × 3 inches, top rail 5 inches × 3 inches tapering down to 3½ inches × 3 inches, rails and bracing 3½ inches × 1 inch, the latter double. The 13-foot gate should be half an inch thicker and have a solid bottom rail. The top of the gate should be even with the top of the fence, and the posts should be fixed 4 feet in the ground.

**Large Gates.**—A drawing of a large sliding gate is given in Fig. 17, where it will be seen that the spindles of the rollers themselves

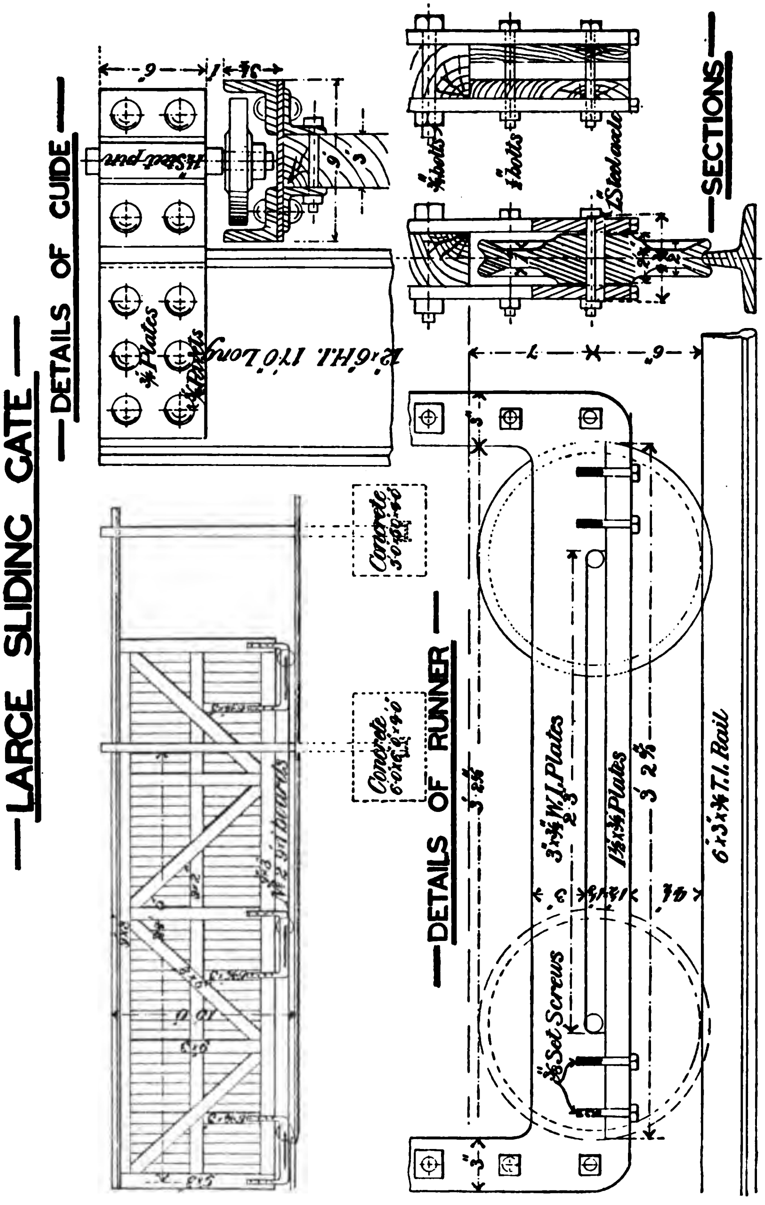

LARGE SLIDING GATE
DETAILS OF GUIDE
DETAILS OF RUNNER
SECTIONS
1½" Steel pin
12"×6" H.I. 17'0" Long
¾" Plates
¾" Rivets
Concrete 3'0"×3'0"×4'0"
Concrete 6'0"×4'0"×4'0"
¾" bolts
1" bolts
1½" Steel axle
¾" Set Screws
3"×¾" W.I. Plates
1½"×¾" Plates
6"×3"×¾" T.I. Rail
3' 2⅝"
7"
9"
3"

FIG. 17.

are allowed to roll to reduce the friction. The top girder and all the iron work has been calculated to sustain a wind-pressure of 14 lbs. per square foot without being strained to a greater extent than 5 tons per square inch.

**Cattle Guards.**—Gates may be dispensed with if the fences are brought to 4 feet from the rails, and hard-wood arris rails, about 7 feet 6 inches in length, are put parallel to the metals to fill up the gap, as in Fig. 18. Cattle will not attempt to walk over these, especially if they can see water in a grip cut below.

**Guard Stones.**—These are sometimes necessary to protect the fencing where there is no kerb; they may be made 2 feet long, 8 inches out of the ground, 9 inches diameter above, and 2 feet square below ground.

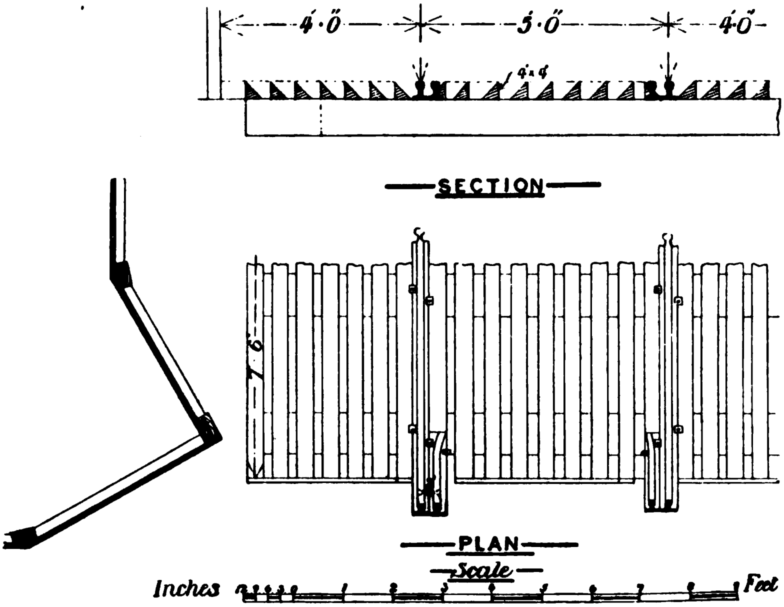


FIG. 18.

**Setting out Fencing.**—Fencing is generally set out in the following way, if two reliable men are at hand. The ends of two tapes are held at the chain-points, and the tapes are made at right angles to the centre line. The assistant engineer then reads out the dimensions from his half-width book, and pegs are put in. If his men cannot be trusted to read the tape, he must himself hold the two boxes and give the distances from the centre. With only one tape the progress would be very slow and unsatisfactory.

When cross-sections have not been taken and the ground is at all sloping or "sidelong," it is necessary to use a level, and the operation is performed in the following way. The half-width at formation level is added to the width of the cess and to the height of the bank at the centre, multiplied by the ratio of the slopes, and this distance is set out. Thus, assuming the formation width, in the case of a double line, to be 28 feet, the cess 12 feet, the height of the bank 20 feet, and the slopes 1½ to 1, the fence-peg would be put in at a distance from the centre of $14 + 12 + 20 \times 1\frac{1}{2} = 56$ feet. If the ground slopes away from the centre line the staff should be held at the centre and then near the peg, and the difference, multiplied by the ratio of the slopes, is added (or deducted in the case of a cutting), and the peg moved further away accordingly. A second correction is then made, but this is not generally necessary, as the staff may be held a little beyond the peg in the first instance, *i.e.* at the place where it is expected to come. The widths actually set out should be booked and marked on the plan. This mode of setting out slopes does not save time in the long run, and is unsatisfactory, but it is, nevertheless, sometimes employed.

**Occupation Roads.**—It is not usual to buy land for occupation roads, but it is necessary to put a fence at the top of each slope, as in the case of public roads. The bottoms of the slopes need not, however, be fenced except to keep cattle off while the young grass is growing.

**Notice-posts.**—The mile and quarter-mile posts should be out of 5-inch × 5-inch fir, cut diagonally, and the figures should be painted on 1½-inch boards 9 inches deep, which must be securely nailed on to them. The gradient posts should be 6 inches × 4 inches in size with 6-inch × 1½-inch gradient boards morticed into them. The speed and notice posts which have to be fixed at 300 yards and 50 yards respectively from the level crossings where gates are not put should be 6 inches square. These latter must stand 5 feet out of the ground, but the mile and gradient posts need not be so high.

# CHAPTER V.

## *EARTHWORKS.*

**Slopes for cuttings and banks—Formation width and cess—Height of rails above formation—Bottom ballast and drains—Road approaches—Slips—Sidelong ground, benchings, and stripping of turf—Slurry, snow, and high tips—Superficial and deep-seated slips—Quicksands and bogs—Burning clay—Drains, stone toes, and timber piling—Easing slopes—Examples of slips, and methods of dealing with them—Recommendations as to how to avoid slips, and to deal with them when they do occur—Execution of earthwōrks—Fixing centre line and levels—Temporary roads—Excavation by hand and steam navvy—Tipping —Backing up bridges—Soiling and trimming slopes.**

UNLESS there is something very exceptional in the nature of the works, it is always the cuttings and embankments on a railway which cause the greatest trouble and anxiety, both in construction and maintenance. It is, therefore, necessary to exercise the greatest care to avoid bad ground in laying out a line, and to take, during construction, such precautions as shall, as far as it is possible, ensure the safety of those portions of the works where bad ground has unavoidably to be encountered.

In cuttings the slopes which have been adopted vary from perhaps ¼ to 1, in the case of hard rock, to 3 to 1, or even more, in the case of bad clay. Chalk and the soft rocks may be put at about ¾ to 1, but the latter need not be trimmed so far back as this, for they will slowly keep breaking up with the frost, until after many years they assume this slope of themselves. Where, as is often the case, there is soft ground over the rock, this should be trimmed to the ordinary earth slope, and a benching left on the top of the rock of such a width as will admit of the rock eventually forming the 1¼ to 1 slope, unless indeed it is very sound and imperishable. Blue clay, red marl, dry sand, and all ordinary soils may for shallow cuttings be put at 1½ to 1, and bad-looking yellow clay at 3 to 1.

For embankments nothing steeper than 1⅜ to 1 is permissible, and for bad material 2, 2½, and even 3 to 1 slopes are common.

It is usual to take land and to commence the work on the assumption that the slopes are to be 1½ to 1 both in cutting and bank throughout, and to vary them afterwards as circumstances may from time to time dictate. It is also often advisable to take sufficient land for a double line, and to give a good cess of, say, 12 feet from the edge of the double-line slope to the fencing.

The width at "formation level" should, in general, not be less than 17 feet for a single line, nor less than 28 feet for a double line, when the rail-level is 2 feet above formation. By "formation level" is meant the top of the bank or bottom of the cutting on which the ballast rests. The formation should be made with a fall of a few inches from the centre to the side, in order that the water may be carried off.

For the ordinary chair road the earthworks are always finished off to an average level of 2 feet below the top surface of the rails, which is known as "rail-level." When the Vignoles rail is used, however, 3 inches less than this is required, *i.e.* 1 foot 9 inches, which may be made 1 foot 6 inches or even 1 foot 3 inches by reducing the thickness of the bottom ballast.

On the formation from 12 inches to 6 inches of bottom ballast or pitching is placed before the permanent way is laid, and from the sides of this, on the banks, short drains about a foot square in section ought to be laid to carry the water on to the slopes, to prevent it soaking into the bank, and it is better for these to be continued right under the ballast to meet in the centre. The bottom ballast should be as rough as possible, and nothing is better than lumps of iron slag, with the interstices filled in with broken slag, and on this some finer material of a dry, clean nature free from sand should be spread.

In the cuttings a drain-pipe on each side is generally put, 2 or 3 feet below formation level, and this should be covered with stone or burnt ballast and have all the side drains run into it, to keep the cutting as dry as possible. It may be argued that to put in this drain it is necessary to cut into the slope, and so weaken it at the most important point; but, if it is not kept open too long, the stone-filling should be able to resist the thrust at the toe as well as the material which is taken out. Unless the cutting is very long, 6-inch pipes will usually be sufficient. Glazed socket-pipes should be used, but the joints must not be cemented or clayed. Manholes, 4 feet long and 2 feet wide, with catch-pits a foot below the invert, ought to be placed 5 chains apart to prevent the pipes getting blocked up.

A half-section of a cutting showing the drains, slopes, and benching is given in Fig. 19.

The formation width for a road approach in embankment should be 5 feet wider than the width of the road, to enable the fencing to be firmly fixed. In a cutting it may be 2 feet less than the width of the road, the level of formation below the top of the metal being generally taken as a foot.

**Slips.**—Water is the chief cause of slips, and it must be intercepted wherever it appears in the sides of the cuttings. Agricultural drain-pipes laid parallel with the fences some distance outside them at a sufficient depth to cut off the land drains, as shown in Fig. 19, are useful for this purpose. They can often by agreement be so laid, and, if 4 feet deep and covered with rough stone, will intercept all the surface-water. Deep-seated springs can be dealt with by leading rough stone drains, 2 feet wide and 4 feet deep, up the slopes to them.

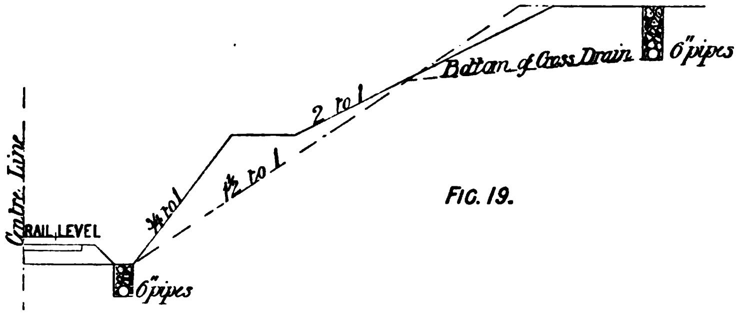


FIG. 19.

Embankments on soft ground often force up the surface of the adjoining land, unless their seats can be well drained, and a great saving may often be effected by so dealing with them. Where they rest on sidelong ground, benchings about 3 feet deep should be cut to form a bond, and prevent the bank which is being tipped sliding bodily over the surface. For the same object, the turf at the toe of the slope should be removed, for it makes a kind of lubricated surface for the bank to slide on. Deep trenches along the centre line and toes of the slopes help to hold wet and slippery material, while cross-drains often prevent it running ahead longitudinally.

Embankments should always be tipped to the full width in the first instance, and the side-tips should be kept well in advance of the centre ones, due allowance being made for shrinkage. No slurry or soft material must be shot over the head of the bank, but it should be loaded into side-tip waggons and run to spoil. All snow must be removed from the bank before fresh material is tipped over it—in fact, every possible precaution should be taken to lead the water away, and not to let it sink into the bank. No material of a doubtful nature should be tipped to a greater height than 30 feet at one time, and the slopes should be trimmed, soiled, and sown as soon as possible for the turf to protect them from the action of water and air, for clay will soon swell when exposed to the air, and the slow progress on a high tip tries it a good deal in this respect.

When a slip occurs in the side of a bank during construction, it is necessary to get past it in the best way possible with a single line, and to widen out to the full width beyond, the slip itself being made good afterwards with light material, or otherwise dealt with. When the material in being tipped runs away in a forward direction, it is necessary to cut cross-drains, as before described, and fill them with large stones, or to stop the work, if the weather is bad, and wait till it improves.

Slips may be mainly classed under two heads—superficial and deep-seated.

Superficial slips are due to the water washing out the face of the slope and endangering the stability of what is left behind. These local slips may be dealt with by clearing them out *to the bottom* and replacing the soft material with stone or burnt ballast, but sometimes they indicate that the slope is too steep, and it must be dressed to an easier batter, and even then it may be necessary to cover it with burnt ballast as a protection before the soil is put on. A stone toe, 3 or 4 feet square, with counterforts about 20 feet apart, may even sometimes be required.

The deep-seated slips are more difficult to deal with. The ground will frequently break away and slide down on a vertical line at the back, and this may occur at the very centre of the line in a bank, or near the fencing in a cutting. There are several ways in which they may be treated.

(1) The whole of the material which has slipped may be burnt and wheeled back into its original position.

(2) A series of drains or counterforts from 4 to 10 feet wide may be put about 20 feet apart, each one going *below the bottom* of the cleavage line and well into the solid at the toe of the slope.

(3) The bottom of the slip may be weighted with stone or slag, and the top made up with light material.

(4) A deep drain of stone or burnt ballast may be put in at the back of the slip, with cross-drains down to the toe of the slope to carry off the water.

Quicksands require holding up by dry walls or sheet piling, or they may be drained by open, close-timbered trenches.

Where the ground underneath a bank is unable to carry the weight and sinks, causing that outside to rise, and everything has been done in the way of drainage, there is nothing for it but to keep on tipping until equilibrium is established.

There are certain soils which will not stand safely at 1½ to 1 when over a certain height, and it is economical to make the slopes 1½ to 1 for the top 20 feet, 2 to 1 for the next 20 feet, and 3 to 1 for the remaining height.

The following are some examples which will be found useful in dealing with many of the different kinds of slips which are met with. They are mainly taken from the six papers on this subject in vols. lxii. and lxvi. of the *Proc. of the Inst. C.E.*

In the boulder clay on the Nottingham and Melton line[1] no movement took place, but, where pockets of sand occurred in the shale and clay, portions of the slopes which were trimmed at 2 to 1 would slide forward, leaving a vertical face behind, this action being due to the presence of water. When these slips were small they were cleaned out, and the line of the slope made good with stone or burnt ballast; but in one case, in which the mischief extended for a length of 6 chains and to a depth of 40 feet, a drain parallel to the railway, 4 feet wide, was put in at the back, with a number of cross-drains to carry the water from it to the toe, which latter was secured by burning the clay for a width of 20 feet.

In one instance a slip occurred on each side of a cutting through the lias shales on this line, and the formation was lifted up some feet. This was dealt with in the same way as before, and the toes were secured by digging out the ground which had moved below the formation and filling up the space with iron slag, the depth so removed varying from 3 to 9 feet.

A cutting, 50 feet deep, through red marl on the same line stood well with 1½ to 1 slopes.

A number of superficial slips took place in the cuttings and banks of the Saxby and Bourne Railway. In the case of the banks, a stone toe, 9 feet wide and 6 feet high, was put in, and from it a series of counterforts, 4 feet wide and 6 feet deep, were run up the slope 16 feet 6 inches apart, centre to centre, and the space between was made up with burnt ballast.

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[1] *Proc. Inst. C.E.*, lxvi. 256.

Some of the cuttings were trimmed to an easier batter, and stone drains, 2 feet 6 inches wide and 4 feet deep, were put in, the slope in one instance being afterwards covered with a foot of burnt ballast before the soiling was done.

Most of the slips on this line occurred after everything had been done in the way of drainage to guard against them. In one case a 6-inch drain-pipe, 4 feet deep, covered with stone to the surface, was laid about 20 feet outside the fence with good regular falls, and stone drains, about 15 feet apart, were put in the slopes, but the ground between these kept breaking away owing, no doubt, to the water, which caused the mischief, and which must have been below the level of the 6-inch drain-pipe, not being tapped by the slope drains. It would, perhaps, have been better to have adopted the system made use of on the Nottingham and Melton line, of putting a deep drain at the back of the slip parallel with the railway, for although the cutting was 35 feet deep, it was only the top 10 or 15 feet which gave any trouble, the lower portion being of a rocky nature.

The deep-seated slips on this line had trenches 6 and 9 feet wide excavated to the bottom of the slip, and these were filled up with rough stone.

On the Byker [1] branch of the North Eastern Railway an alluvial clay of a tenacious flaky nature was met with. This was generally burnt where it gave way, and the slopes were made up again with the ballast resulting. In some cases the back line of the slip, which was near the fencing and almost vertical, here extended to below formation level.

The clay from the cuttings when deposited in the banks also moved in many instances, and was treated in the same way, but the burning was carried out in narrow sections so as not to let the mischief spread. Some of the worst of the clay was tipped to spoil, and, as a measure of precaution, in the case of one deep bank the surface of the ground was covered with brushwood to a depth of 3 feet, and this effectually drained it, and no trouble was experienced. The cost of the burning was less than two shillings per cubic yard, but it must be remembered that coal was cheap and the clay well fitted for burning.

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[1] *Proc. Inst. C.E.*, lxvi. 263.

In a 60-feet cutting on the Leeds and Wetherby branch of the North Eastern Railway[1] a mass of soft argillaceous clay, which burnt freely, slipped without any warning long after the line had been opened. This was 35 feet thick, and was dressed at 1½ to 1, a cess of 5 feet being left between the toe of this slope and the top of the 1 in 6, which the rock below was put at. A narrow grip was cut at one end, and a fire started and carried right through the cutting, the burnt ballast being left at 1¾ to 1.

In Fig. 20 is given a section illustrating what took place in a cutting on the Castle Eden and Stockton Railway.[2] Some drains, about 3 feet wide and 20 feet apart, carried to a foot below the seat of the disturbance, were taken out and the vacant space filled with slag. A retaining wall, with dry filling behind, was built at the toe of the slope, and the hollows were filled up with ashes and soiled.

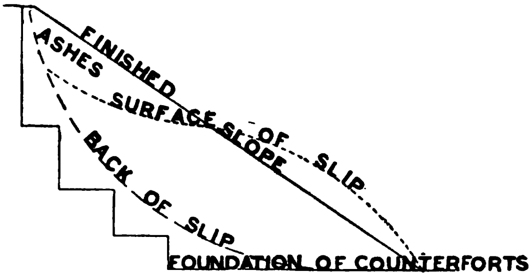

FIG 20.

In some instances on this line the whole of the material which had moved was burnt and replaced. The embankments were here a constant source of trouble, especially in winter, the material which was tipped often running far beyond the company's land. Ground which had moved in this way had to be passed by a single line, and the void made good with ashes in dry weather. In some cuttings the clay was only stopped from working up between the sleepers by cutting deep drains on each side of the ballast.

On the Shawforth Railway[3] the sides of a road approach came in, and had to be retrimmed to a 2 to 1 slope, a retaining wall being put in at the toe, in addition to numerous stone drains up the slopes.

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[1] *Proc. Inst. C.E.*, lxii. 285. [2] *Ibid.*, 280. [3] *Ibid.*, 275.

A quicksand was encountered on this railway in a cutting 50 feet deep. The slopes had been laid out at 1 to 1, but they had to be altered to 2 to 1, and in some cases to 3 and even 4 to 1. A row of piles was driven along the toe of the slope, and a stone drain 3 feet square was put in at the back.

Similar slips to this occurred in some very shallow cuttings near Swindon. In one case the ground moved from a very long distance, and had to be held back by sheet piling, and in another the line had to be diverted.

A number of embankments and embanked approaches between Ashby and Nuneaton[1] failed, owing to the perishable nature of the clay. In some cases this was all burnt, and in others it was allowed to form its own slope, and then drains, 3 feet wide and 30 feet apart, were run up the slopes.

A great deal of trouble was given by the Sway bank near Bournemouth.[2] This was 60 feet high, and was designed with 1½ to 1 slopes, but before it could be got to stand the height had to be reduced to 50 feet, and the slopes made 2½ to 1 with two 10-foot benchings. A wall 12 feet by 14 feet was put at the toe of the slope, and from it counterforts 10 feet wide and 15 feet apart were run up the slope, some of them being of great depth.

A failure of a somewhat exceptional character took place in a cutting near Huddersfield.[3] The ground was sidelong, and the strata consisted of rock sloping with the surface with the shale below it. The shale perished under climatic influence, and the rock above it kept tumbling in. It was found necessary to build a retaining wall to hold back the *débris*, and to carry counterforts from it to support the rock above.

Another rather unusual case occurred near this cutting. An embankment of good material, resting on sidelong ground of a rocky nature, moved bodily down the hill, the superficial coating of rock evidently sliding on the more solid rock below. The movement was not extensive, however, and the bank was easily made good with some more material.

On the Shawforth branch near Rochdale[4] the material, which was tipped into a high bank, being of a soft, wet nature, would not stand at any slope, but ran straight ahead, in a series of waves. It was found necessary to recentre the viaduct, and run up to it on trestles, and to leave the slip for a time, carrying the material over to the other side of the viaduct. Dry stone drains were then put in, and the bank made good with dry filling.

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[1] *Proc. Inst. C.E.*, lxii. 276.

[2] *The Engineer*, March 23, 1888.

[3] *Proc. Inst. C.E.*, lxii. 273.

[4] *Ibid.*, 274.

On the Castle Eden and Stockton Railway[1] a bank on a marsh squeezed up the soil on each side, raising a mound as high as the formation level. The bank itself went down to the solid ground and raised a bank of peat in front of it as it advanced. In one case a bog 16 feet deep was dug out before the bank was tipped.

The writers of the papers referred to[2] make the following recommendations as the best means of preventing slips:—

(1) The slope to be 2 to 1 for heights of from 25 to 40 feet for both cuttings and banks.
(2) The bank to be tipped to the full width, and ample provision made for shrinkage.
(3) The turf to be stripped and benchings to be cut on sidelong ground.
(4) A coating of at least 6 inches of burnt ballast to be laid over the slopes before the soil is laid on.
(5) That no embankment of clay or loose material should be tipped to a greater height than 20 feet at one time.
(6) That no side ditch or cutting should trespass on the line of slope above it.
(7) That soft material, such as peat, should not be tipped in bad weather.
(8) That all snow should be cleared from the tip-head.
(9) That clay should be formed at 2 to 1, even if it stands for years at 1¼ to 1.

As the best ways of treating slips when they do occur, they recommend—

(1) The burning of the toe of the slope for a width of from 8 to 20 feet to a depth of 2 feet below the solid ground-line.
(2) Counterforts from 3 feet wide carried down to 2 feet below the slip, but not taken quite up to the top of the slip.
(3) Burning the whole of the material which had moved.
(4) Sinking a trench at the back of the slip parallel with the centre line, and filling it with stone or burnt ballast.

Burning clay increases the bulk some 25 per cent., and costs two shillings a cubic yard and upwards. With good burning clay a ton of coal will convert 10 yards to ballast.

**Execution of Earthworks.**—A cutting is often begun before the fencing is put up, so that the dimensions from the fences to the centre pegs, which should be measured as described in Chapter III., often cannot be taken at the places where they are the most useful, viz. at the prick of the cutting, unless indeed the line is again ranged by means of the theodolite; and this will often save time in the long run. The tangent lines should, if possible, be marked on the fences, and the positions of the tangent points should also be carefully marked.

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[1] *Proc. Inst. C.E.*, lxii. 280

[2] *Ibid.*, 278, 283; and lxvi. 259.

In some cases, especially when there is a downward gradient, cuttings are not taken out to the full depth in the first instance, and a temporary formation line must be plotted on the section and the depths calculated for the use of the ganger. Knowing that he is so much high, he will be able to estimate what his widths at that level will be, and he will also have the top widths to work from, for the tops of the slopes at each chain-point should be set out and nicked before any work is done. It economizes time to set out the slopes at the same time as the fencing, the distances of these from the centre line being noted in the half-width book. Uprights, with one cross-head to show the formation level, and another the level to which the bank is to be tipped to allow for settlement, must be erected at each or every other chain-point in the bank as guides for the men on the tip-head.

The excavation is begun by means of barrows only for a distance of about a chain, and small cuttings are often taken out entirely by handcarts or by dobbins, or three-wheeled carts which will turn about in any direction for shooting the earth. When the lead gets too long it is necessary to lay in a temporary road and employ tip-waggons. It is generally considered that 3-yard waggons, running on the 4-foot 8½-inch gauge, are preferable to 1½-yard waggons on the 3-foot gauge. The waggons are drawn out of the cuttings and tipped by horses until the lead is sufficient to warrant the employment of an engine, and then collars may be added to the waggons to increase their capacity.

Sometimes, in a deep chalk cutting, a heading is driven, and the waggons are filled through shoot-holes.

When the work is done by hand it is, however, more usual to drive a narrow gullet some 10 or 12 feet wide, and to follow this up by excavating the sides.

In average ground, sixteen sets a day, and twelve waggons in a set, would indicate good progress, with three men to a waggon, and perhaps two extra men to each gullet-waggon, several to trim the slopes and to attend to the roads, and in addition two on each tip.

The way in which a cutting is taken out will be better understood by reference to Fig. 21. The full waggons are drawn out and left in the position **AA**, while the engine pushes the empties back from **BB** into the cutting **CC**. It then, by means of the loop **BB**, gets in front of the waggons, and draws them on to the bank, leaving all but one in the position **DD**. It runs fast ahead with this one, and, slightly slackening the pace, uncouples it, and runs ahead again fast over the points at **E** on to the road **G**, the waggon being turned by a boy at the points **E** to **H**. The engine then runs back and picks up another waggon, which it "fly shunts" as before, but this time it runs to **H**, and the waggon is sent to **G**. The engine stops in **H**, picks up the waggon standing there, and sends it forward with sufficient velocity to tip it; then, coupling up again, it draws it back, and, again by means of a "fly shunt," sends it into the siding for empties **KK**, and runs itself to **DD** to pick up another waggon, and continues the operation. When the waggons are all tipped they are drawn out of **KK**, and pushed back into **BB**, where they remain until those in the cutting are full. If a second engine is used for tipping, and one will only deal with perhaps 200 waggons a day, it is necessary to make **KK** into a loop, and to provide another siding for spare and damaged waggons. The actual time spent in tipping is a little over a minute, but delays occur owing to waggons being sent over the tip or getting off the rails, and it is most necessary not to keep the men in the cutting waiting. It is generally necessary to have three times as many waggons as are worked in a set, besides a few more to allow for repairs. A water-tank, coal-stage, and engine-shed must be provided at some convenient spot, as well as every facility for repairing the engine as quickly as possible when it breaks down.

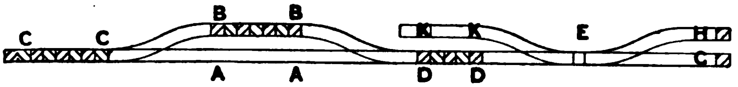

*FIG. 21.*

When a cutting exceeds a certain size it is generally economical to employ a steam navvy. This works best in a depth of perhaps 15 feet, and so a deep cutting is generally taken out in two or more lifts; and besides, especially in a single-line cutting, this gives more room to work. A plan showing how a navvy is worked is given in Fig. 22. The empty waggons in **BB** are drawn forward by horses to **C**, and when full to **AA**. The instant a waggon is full, one horse draws it out from **C** to **A**, and another draws an empty one forward from **B** to **C** to take its place, drawing it in the same way as if it was going to be tipped, and then unhitching. A fresh waggon is thus in position almost as soon as the skip is full. The narrowest width that a Ruston and Proctor's navvy can work in is about 20 feet at formation level. It runs on a gauge of 10 feet 9 inches on two pair of rails, and generally requires 12-inch by 6-inch sleepers, 2 feet apart centre to centre, to carry it. It will fill 200 waggons a day, but when allowance is made for moving it about, for breakdowns, and for slips, the daily average is much less than this, and probably not more than 100. A sufficient number of men should be employed to take off what is left of the slopes at once, in order to prevent slips in bad weather, and generally to finish up the cutting behind the navvy.

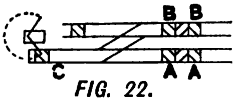

*FIG. 22.*

When the railway crosses a road in a cutting, a temporary bridge, together with a diversion of the road, is required, unless it is possible to sink for the foundations and build the bridge before the cutting is up to it. There is not often time to do this, however, as it is important to get the bridges and culverts in the banks built first.

When the tip approaches a bridge it is necessary to wheel the earth forward, to put a counter-balancing weight on the opposite side, and to well ram the earth. If the crown of the arch is at formation level, an average width of 7 feet 6 inches is generally sufficient, in addition to the foot of dry lining which should always be put behind the walls to carry off the water and relieve them from hydrostatic pressure. When the crown of the arch is below formation level, a timber gantry should be run over the bridge in order that a mass of earth may be placed beyond, directly the toe of the slope touches the first abutment. Care is also required in tipping over culverts, but the best precaution is to build these well down in the solid ground.

Heavy works may be encountered on a light railway, so it has been thought necessary to go at some length into this subject, although shallow cuttings and banks presenting few difficulties are more often the rule.

A considerable saving in the way of plant may be effected in executing the earthwork, by casting out a gullet and laying the permanent way at once in this and along the cess by the side of the banks, and using side-tip waggons. If the permanent way is so laid, the work must be done by engines and not horses, which would damage the sleepers, and it must be partly ballasted so that the rails may not be crippled. It is a little dangerous to do the work in this way, however, and it is better to employ a 3-foot gauge temporary road with 1½-yard waggons, or a 2-foot gauge road with ½-yard iron waggons, either of which can be laid in the gullet and along the centre of the bank, and lifted from time to time as this is raised.

The top spit must be saved for soiling the slopes by wheeling to the sides of both cuttings and banks.

The slopes are trimmed by cutting section-marks at the chain-points, from the slope-pegs to a peg indicating the edge of the formation, and batter rules are useful in cutting these. When the slopes have been trimmed they must be soiled to a depth of at least 4 inches, and in the early autumn or spring sown with rye-grass seed, 30 lbs. to the acre, everything being kept off the slopes while it is growing.

# CHAPTER VI.

## *BALLASTING AND ROADS.*

**Settlement—Faggots—Bottom and top metal—Binding—Rolling—Local byelaws—Kerb and channel—Footpaths—Gulleys—Drains—Pitching—Coal-stacking grounds—Bottom and top ballast—Boxing up—Burnt ballast, iron slag, gravel, stone—Allowance for consolidation.**

In preparing the surface on a raised road approach, proper allowance, both in the height and the width, must be made for settlement. On soft ground it is a good thing to cover the formation with faggots. The bottom metal, which ought to be 8 inches thick for a public road, should be rolled with a 10-ton steam-roller, and all holes made good before the top metal is put on. This latter should consist of stone, broken to a 2½-inch gauge, and should be 6 inches thick for a public road, and, like the bottom metal, somewhat less for a private road. A thin coating of marl and screenings from the gravel pit must be spread over this, and plenty of water used while rolling. Where the foundation is good the surface might be covered with a layer of broken granite, but it is a waste of money to put granite on newly made banks—it is more useful a year later. The best materials for the road foundation are iron slag, large flat stones, flints, and *hard* brick rubbish, the spaces between the large stones being filled in with smaller pieces. For the top the choice is limited to *tough* broken flints, crushed slag, granite or other hard rock. The binding material should be loamy and not sharp, and round stones should be everywhere avoided.

A section of a road, made in accordance with the usual urban byelaws, is given in Fig. 23. These byelaws are not binding on a railway company, but show what those who have to deal much with road traffic consider necessary. The minimum width generally specified for the road is 24 feet, and for the paths 6 feet each, *i.e.* 36 feet in all. The centre of the road must be from 4½ inches to 9 inches and the kerb from 3 inches to 7 inches higher than the gutters. The footway must fall towards the kerb at 1 in 24 if gravelled, and at 1 in 24 to 1 in 48 if paved. When thoroughly rolled the 8 inches of bottom metal will be compressed into 5 inches, and the 6 inches of top into 4 inches. The paving may be of York stone, concrete, or so-called asphalt, 3 inches thick in each case, and it should be laid on a bed of hard core also 3 inches thick.

The concrete should be mixed in the proportion of 1 of cement to 6 of clean, sharp, angular gravel, iron slag, or similar material, and should be finished on the top with ½ inch of cement rendering —1 of cement to 1 of coarse, sharp sand. It should be laid in sections some 8 feet square by means of temporary splines.

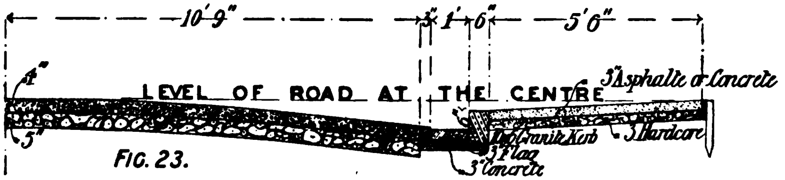

FIG. 23.

Asphalt should be made of limestone chippings boiled in tar and laid on in two coats, the second being only ½ inch thick, and sanded over with quartz dust. Both this and the cement should be kept well above the kerb, for even if well rolled and watered the hardcore foundation may settle a little.

A 10-inch × 6-inch granite kerb set on 3 inches of concrete with a gutter 12 inches wide completes the roadway. The gutter may be of stone, concrete, blue bricks, pitching, or of the scoriæ flags which are cast from the slag as it runs from the cupola. In Fig. 23, 12-inch flags are shown with a row of setts outside. The gutters should run into glazed earthenware gulleys 3 feet deep, 18 inches diameter, with cast-iron hinged gratings. These will become untrapped in dry weather, but where they are put the roads are generally watered, and so the water-level is maintained in them. The drains from these should be perfectly straight, and laid to a true gradient of not less than 1 in 264, to ensure a regular flow fast enough to prevent the deposit of silt. All manholes and gulleys should be pitched round with three or four rows of 4-inch granite cubes.

In roads where there is much traffic the whole road should be pitched, the granite cubes or wood blocks being laid on 6 inches of concrete and grouted in with 3 to 1 cement grout. Where a railway crosses a public road, or runs along the same as a tramway, the space between the rails and 18 inches outside should also be pitched. For coal-stacking grounds it is sufficient to put down chalk, or something equally cheap.

The drainage may be towards the siding, but it is perhaps better to drain away from it. All drains should have manholes about 5 chains apart, to admit of inspection and cleaning, for a good deal of silt will often be washed into them. These will be dealt with in detail in the chapter on Drainage.

In ballasting a single line, the ballast should be laid 12 feet wide and a foot thick before the sleepers are put down for a first-class line of 4-foot 8½-inch gauge, but this may be reduced for a lighter line. This bottom ballast should, in cuttings, consist of rough slag, large durable stone, or the like; but it is wasteful to go to any great expense to get good bottom ballast for laying on newly made banks. The formation should be a few inches higher in the middle to ensure good drainage. The permanent way, when laid on the bottom pitching, should be a little low, so that when the top ballast, which must pass a 2-inch gauge and be free from sand and loam, has been added the line can be lifted and packed to true lines and levels, and then boxed up with the same material to the top of the sleepers, beyond the ends of which it should extend some 6 inches. On banks burnt ballast may be good enough to use at first, but it should be replaced by slag after a few years. What is wanted for ballast is something that gives good drainage and does not perish with the weather or the hammering action it is exposed to. Nothing is more suitable than iron slag, but there are many kinds of gravel, flint, and rock that do equally well—Kentish rag and some of the harder limestones, for instance; but some rocks requiring dynamite to blast them go to pieces and turn into mud when exposed. Anything also that makes much dust is injurious to the rolling stock.

In ballasting a running line, time is of great importance, and instead of taking a number of men with the train, the bottoms of the trucks are often made to drop, and the ballast is spread by means of a plough fixed to the rear van. In allowing for ballast, provision must be made for consolidation, as in the case of roads rolled by a steam-roller, but in this case it is sufficient to allow for a reduction in bulk of 25 per cent.

# CHAPTER VII.

## *PERMANENT WAY.*

**Various systems—Strains on the rail—Calculations and table of the strength of various sections—Comparison between theory and practice—Iron *versus* mild steel—Wood and steel sleepers—Fastenings—Gauge at points and crossings, and on curves—Cant—Junction work—Table of angles of crossings—Setting out junctions and curves—Short rails—Tramways.**

Many systems of permanent way have been tried, but there are only three that have been found to stand the test of experience, and, for heavy traffic, the bull-headed rail in chairs is now all but universal, the old Great Western longitudinal road, satisfactory as it was, being now but little used, and the Vignoles **T**-rail, fastened by clip bolts, being more suited to lines of small traffic.

The chief circumstances affecting the design are the maximum weight on the wheels, the speed, the curves and gradients, and the amount of traffic. A heavy engine, with 18 tons on an axle, running at a high speed, will, in rolling from side to side, by compressing the springs, increase the load on either wheel from 9 to perhaps 12 tons by reducing that on the other to 6, and a curve which has not sufficient cant will still further increase the pressure by reason of the centrifugal force which, to take the extreme case, at the moment of overturning would throw the whole weight that should be carried by a pair of wheels on to one of them. When the curves are sharp, the gradients steep, and the traffic heavy, considerable provision for wear must be made in the rail-head.

The three systems that have been referred to are illustrated in Figs. 24, 25, and 26.

The characteristic features of the longitudinal road (Fig. 24) are the "bridge rails," 6 inches wide and 3 inches deep, weighing 70 lbs. per yard, resting, through the medium of pine packing, on longitudinal timbers 14 inches wide by 7 inches deep, which are

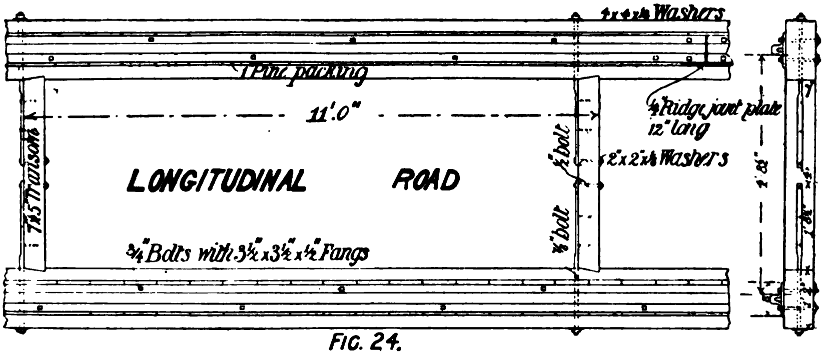

FIG. 24.

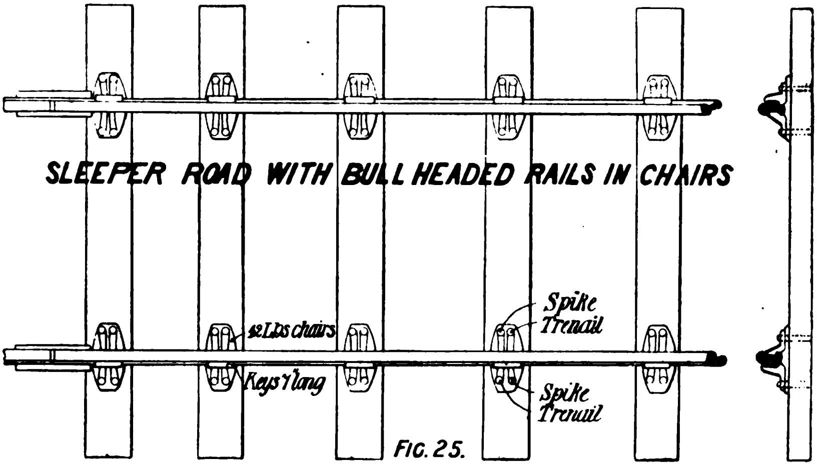

FIG. 25.

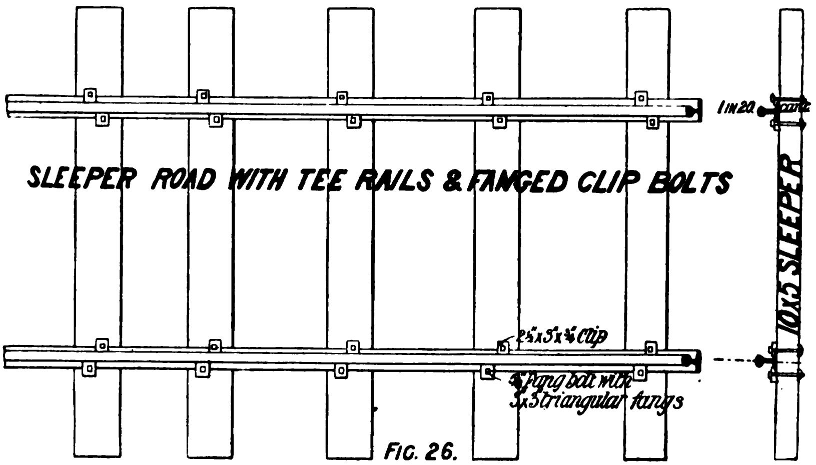

FIG. 26.

tied together by 7-inch × 5-inch transoms spaced 11 feet apart. The rails are fastened to the timbers by fang bolts, and the timbers to the transoms by strap bolts or tie-rods. The rails are not fished at the joints, but simply rest on iron plates. As will be seen in Appendix K, the first cost is heavy, but this is compensated for by the longer life of the timber.

Fig. 25 illustrates the chair road. The 84-lb. bull-headed rails are here shown as fixed in 42-lb. chairs by means of compressed fir keys placed outside the gauge. Each chair is attached to the sleeper by means of two oak trenails and two iron spikes. The rails, which are 30 feet long, are joined together by fish-plates 18 inches long, $\frac{7}{8}$ inch wide, and 3 inches deep, connected by four $\frac{7}{8}$-inch bolts. A space of $\frac{3}{16}$ inch is left between the rails to allow for expansion. The sleepers are 8 feet 11 inches long, 10 inches × 5 inches in scantling, with a maximum wane of 1 inch, and there are eleven to a rail. The keys are sometimes made of oak, but hold better if of compressed fir, as this swells, and so they do not get loose. For very heavy traffic the chairs have a larger base to enable them better to sustain the outward pressure.

The Vignoles **T**-rail road is illustrated in Fig. 26, where an 84-lb. rail is shown attached to the sleepers by clip bolts. The rail-joints and sleepers are the same as before, but the latter are planed off at the rail seats to give the necessary 1 in 20 cant to the rail.

There is one more system that deserves notice, viz. the Barlow rail, which acted well for sidings and low speeds. This was a saddle-backed rail, weighing 90 lbs. per yard, which rested directly on the ballast; the gauge was kept by angular tie-bars, and there were no sleepers at all.

**The Rail.**—The strains on a rail are somewhat complicated, but, knowing what has been found to be satisfactory for loads of 18 tons per axle, it is comparatively easy to calculate what is required for loads of 12 and 6 tons.

The sleepers give under the weight, and, so long as the rail is fairly rigid, each therefore yields practically the same resistance, so that the span to be considered is not the distance apart of the sleepers, but that of the wheels bringing down the weight.

Taking the case of an engine with axles 8 feet apart and loads of 18 tons per axle, resting on sleepers spaced 2 feet 8 inches centre to centre, three conditions of loading have to be considered.

1st. The wheels may be directly over the sleepers, as in Fig. 27.

2nd. The wheels may be midway between two sleepers, as in Fig. 28.

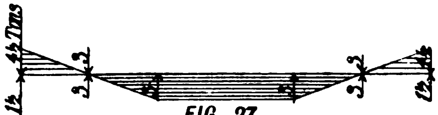

FIG. 27.

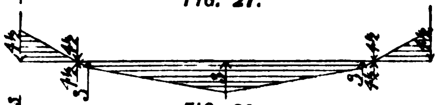

FIG. 28.

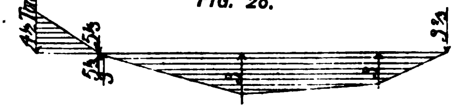

FIG. 29.

3rd. The wheels may be midway between two sleepers, with one wheel over a rail joint, as in Fig. 29.

In the 1st case, treating the rail as a continuous girder with the point of inflection 16 inches from the wheel or abutment, as this really is, we get, putting M as the moment of resistance of the rail—

At the abutment, for the cantilever } $M = 3 \text{ tons} \times 16 \text{ in.} = 48$

At the centre, for the girder } $Mc = 3 \text{ tons} \times 32 \text{ in.} - 3 \text{ tons} \times 16 \text{ in.} = 48$

In the 2nd case, with the points of inflection $13\frac{1}{3}$ inches from the abutment—

At the abutment, for the cantilever } $M = 4\frac{1}{2} \text{ tons} \times 13\frac{1}{3} \text{ in.} = 60$

At the centre, for the girder } $Mc = 4\frac{1}{2} \text{ tons} \times 34\frac{2}{3} \text{ in.} - 3 \text{ tons} \times 32 \text{ in.} = 60$

In the 3rd case, with the point of inflection 15 inches from the abutment—

At the abutment, for the cantilever } $M = \frac{16}{3} \text{ tons} \times 15 \text{ in.} = 80$

At the central sleeper, for the girder } $Mc = \frac{16}{3} \text{ tons} \times 33 \text{ in.} - 3 \text{ tons} \times 32 \text{ in.} = 80$

Under ordinary circumstances the maximum bending moment in inch tons on the rail is thus 60, but this is increased to 80 in the case of a joint.

When all but worn out, the 84-lb. bull-head and the 84-lb. and 70-lb. **T**-rails, when strained to 10 tons per square inch, yield a bending resistance of 80 inch tons.

When the wheel is midway between the sleepers, the joint is as strong as the rest of the rail—so long as the shearing resistance of the fish-plates is sufficient, and the sudden change in the stress from 48 to 80 inch tons, *i.e.* in the case of a worn-out rail of from 6 to 10 tons per square inch in compression and tension, explains the knock that is felt at the rail-joints.

It is clear if the axles are brought nearer together than 8 feet that, although the gross load will be greater, the bending stress will be less.

The lighter rails deflect appreciably under the load, which is therefore carried more by the nearer sleepers, and so the bending moment is less; but, besides being strong enough to carry the load, the rail should not deflect too much under it, and it will generally be found to be a safe rule to make its moment of resistance in proportion to the load per axle.

The moments of resistance of the rails shown in Figs. 30 to 36 are given in the table on the next page.

Experience has shown that the dimensions of these rails are satisfactory.

To find the moment of resistance of a rail is a simple but somewhat tedious process. A position for the neutral axis must be assumed, and, since the resistance of the metal increases from zero at the neutral axis to a maximum at the extreme fibres, a diagram may be drawn as shown in Fig. 33, and the areas of the diagrams on each side the neutral axis must be equal for equilibrium. If they are not, a fresh position must be assumed.

Thus, to take the case of the 56-lb. **T**-rail (Fig. 33), when the top has been worn down to the dotted lines—

Assume a position for the neutral axis **NX**, as shown, 2·05 inches from the top of the head as worn.

Now, if the extreme fibres on the line **AA** sustain a stress of 8 tons per square inch, those 1·025 from the neutral axis will only sustain a stress of 4 tons per square inch, and those 0·5125 off of 2 tons, and so on.

| Description and weight per lineal yard. | Height. | Head when new. |  | Web. | Bottom flange. |  | Amount worn off head in inches. | Distance of neutral axis from base of rail when it is worn out. | Effective flange area in square inches. | Distances of centres of stress from neutral axis. |  | Moment of resistance in inches and square inches. | Maximum load per axle. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Width. | Thickness. | Thickness. | Width. | Thickness (mean). |  |  |  | Head. | Base. |  |  |
|  | inches | inches | inches | inches | inches | inches |  | inches |  | inches | inches |  | tons |
| 84 lbs. bull-head (Fig. 30) | 5·5 | 2·6 | 1·600 | 0·70 | 2·50 | 1·00 | 0·60 | 2·45 | 2·2 | 1·80 | 1·80 | 7·9 | 18 |
| 84 lbs. T-head (Fig. 31) | 5·25 | 2·5 | 1·500 | 0·60 | 4·75 | 0·63 | 0·50 | 2·15 | 2·2 | 2·00 | 1·70 | 8·2 | 18 |
| 70 lbs. T-head (Fig. 32) | 5·0 | 2·25 | 1·330 | 0·50 | 4·50 | 0·56 | 0·30 | 2·15 | 2·0 | 1·90 | 1·80 | 7·4 | 16 |
| 56 lbs. T-head (Fig. 33) | 4·0 | 2·125 | 1·125 | 0·50 | 4·00 | 0·50 | 0·25 | 1·70 | 1·6 | 1·60 | 1·40 | 4·8 | 10 |
| 42 lbs. T-head (Fig. 34) | 3·5 | 2·0 | 0·950 | 0·50 | 3·25 | 0·40 | 0·25 | 1·50 | 1·1 | 1·35 | 1·25 | 2·9 | 7 |
| 28 lbs. T-head (Fig. 35) | 3·0 | 1·5 | 0·750 | 0·31 | 3·00 | 0·35 | 0·15 | 1·25 | 0·8 | 1·20 | 1·00 | 1·8 | 4 |
| 14 lbs. T-head (Fig. 36) | 2·0 | 1·0 | 0·500 | 0·25 | 2·00 | 0·30 | 0·10 | 0·80 | 0·35 | 0·85 | 0·65 | 0·5 | 1 |

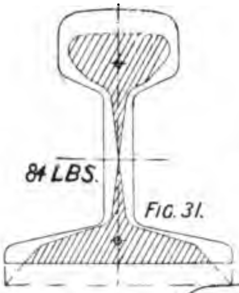

FIG. 31.

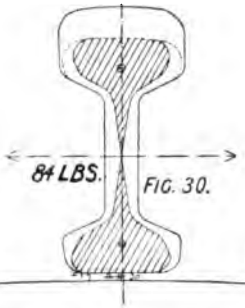

FIG. 30.

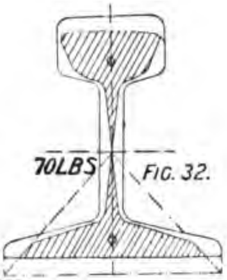

FIG. 32.

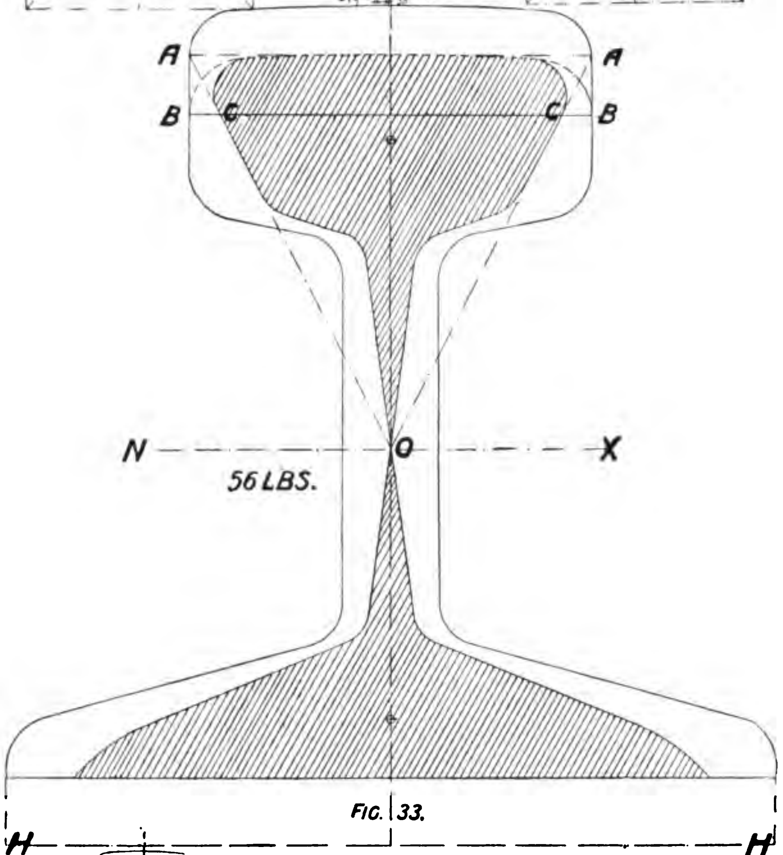

FIG. 33.

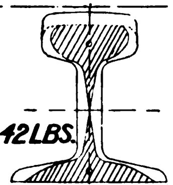

FIG. 34.

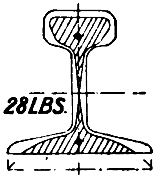

FIG. 35.

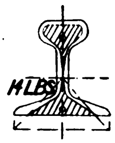

FIG. 36.

A diagram as shown inside the rail-head may thus be graphically constructed by drawing lines from any narrow horizontal strip **BB** at right angles to the neutral axis, to **AA**, and from **AA** to **O**, cutting the line **BB** in **CC**. The area of the narrow strip **CC** multiplied by 8 tons will represent the resistance given out by the strip **BB**. Similarly, any other strips may be taken, and a complete diagram made, remembering that the line **HH** for the bottom flange must be the same distance from **NX** as **AA** is. If the two shaded areas, representing the resistances of the flanges, are not equal in area, a fresh position for the neutral axis must be assumed. In the present case the area of the top flange is 1·58, and that of the bottom 1·56, and these are near enough for all practical purposes, and may be called 1·6.

It will at once be seen that the centres of stress are the same as the centres of gravity of the shaded portions, and their distance apart multiplied by the area 1·6 gives the moment of resistance.

The calculations are—

| For the Top Flange— | | | For the Bottom Flange— | | |
|---|---|---|---|---|---|
| **Area.** | **Moment about NX.** | | **Area.** | **Moment about NX.** | |
| 0·10 × 1·60 | 0·16 × 2·00 | 0·32 | 0·80 × 0·10 | 0·08 × 0·54 | 0·04 |
| 0·20 × 1·85 | 0·37 × 1·85 | 0·68 | 0·20 × 0·25 | 0·05 × 0·90 | 0·05 |
| 0·30 × 1·65 | 0·50 × 1·60 | 0·80 | 0·40 × 1·40 | 0·56 × 1·25 | 0·70 |
| 0·25 × 1·30 | 0·32 × 1·35 | 0·43 | 0·30 × 2·90 | 0·87 × 1·55 | 1·35 |
| 0·10 × 0·70 | 0·07 × 1·20 | 0·09 | | | |
| 0·25 × 0·30 | 0·08 × 1·00 | 0·08 | | | |
| 0·85 × 0·10 | 0·08 × 0·56 | 0·04 | | | |
| **Total area** . . | 1·58 | 2·44 | **Total area** . | 1·56 | 2·14 |
| | | 1·6 | | | 1·4 |

**Hence** $M = 1·6(1·6 + 1·4) = 4·8$

In some of the examples in Appendix H, it will be seen that the calculated weight per axle is slightly exceeded, notably in the case of the 14-lb. rails in Example 2, but, taken as a whole, this table is a very fair check on the above calculations.

Rails are now always made of mild steel, and it needs no showing to prove the superiority of this material over iron. It may, as a matter of history, be stated, however, that iron rails fell into disuse owing to their liability to split and bulge under the load, which was due to the manner in which they were rolled, the pile, owing to the presence of foreign matter, and to the imperfect welding of its parts, not forming a homogeneous whole. Out of 150 iron rails laid in 1864 on the Cologne-Minden Railway, 40 remained in 1876; while out of 150 steel rails exposed to similar traffic, 145 were still in use after the same time.[1] One face of a steel rail at Chalk Farm, on the London and North-Western Railway, outlived sixteen faces of the iron rail opposite to it.[2]

In a paper read before the Institution of Civil Engineers,[3] Mr. Price Williams showed that steel rails on an average wear $\frac{1}{16}$ inch for a total traffic of 10,000,000 tons. Taking $\frac{5}{8}$ inch as the amount that may be worn away, and the annual tonnage as 5,000,000, an average life of 20 years is thus obtained for a rail carrying a main-line traffic.

When iron rails were employed in the chair road it was important to have a second head to rely on in case of the other failing by lamination or otherwise, and hence the double-headed rail was generally used; it was mostly turned after a short time, the nicking in the chair not being sufficient to make a very rough road; but now that steel rails, which have only to be taken out through being actually worn away, are used, there is no advantage in having a second head, because when the first is worn out it would be so much "nicked" as to be unserviceable. The bull-headed rail is now, therefore, practically universal for the chair road. The upper head is made as large as it can be rolled, without endangering the quality of the material; but it is not of much use providing for a much longer life than 20 years, for, after that time, the web would probably have suffered from corrosion and wear at the fished joint.

To give sufficient lateral strength in the connection with the sleepers, Vignoles rails are made as wide as possible.

The steel used must not be too hard, and should give an elongation of not less than 10 per cent. in 2 inches before fracture. It should also withstand a strain of not less than 38 tons per square inch, and of not more than 44 tons. No holes should be punched, but if they are absolutely required, as in the case of the bridge rail, which, by the way, can hardly be considered as a girder, they should be drilled, for punching injures the metal for a considerable distance round the hole actually punched.

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[1] *Proc. Inst. C.E.*, li. 312.
[2] *Ibid.*, xxv. 15.
[3] *Ibid.*, xlvi. 155

**Sleepers.**—The standard size of main-line sleepers is 8 feet 11 inches × 10 inches × 5 inches, and from 1 inch to 2 inches wane is allowed. For junction work and very heavy traffic the size is generally 12 inches × 6 inches, a margin of ½ inch per foot being allowed, so that timbers that are specified as 12 inches × 6 inches may be from 12½ to 11½ inches wide, and from 6¼ to 5¾ inches thick, this being remembered in ordering bolts. Not less than 8 lbs. per cubic foot of creosote should be forced into the timber after it has been thoroughly seasoned. If there is any doubt as to the seasoning, Boulton's process should be adopted of putting the sleepers into creosote of a little over 212° F., to drive off the moisture. There may be a little question as to the necessity of creosoting sleepers that are likely to be worn out by heavy, continuous traffic, but there can be none when decay is likely to be due almost entirely to age.

For light lines, 9-inch × 4½-inch half-round sleepers may be used, and the length may be somewhat reduced.

The comparative prices of the different kinds of sleepers are as follows :—

| | | | *s.* | *d.* | |
|---|---|---|---|---|---|
| 8′ 11″ × 10″ × 5″, | rectangular, with | 1″ maximum wane | 3 | 11 | each |
| 8′ 11″ × 10″ × 5″, | ” ” | 2″ ” ” | 3 | 4 | ” |
| 8′ 11″ × 9″ × 4½″, | ” ” | 2″ ” ” | 2 | 5 | ” |
| 7′ 6″ × 9″ × 4½″, | ” ” | 2″ ” ” | 2 | 3 | ” |
| 9′ 0″ × 9″ × 4½″, | half-round | . . . . . . . . . | 1 | 9 | ” |
| 6′ 0″ × 8″ × 4″, | rectangular | . . . . . . . . . | 1 | 8 | ” |
| 6′ 0″ × 8″ × 4″, | half-round | . . . . . . . . . | 1 | 4 | ” |
| 4′ 6″ × 9″ × 4½″, | ” | . . . . . . . . . | 0 | 11 | ” |
| 4′ 6″ × 6″ × 3″, | ” | . . . . . . . . . | 0 | 4 | ” |

To these prices 2½*d.* per cubic foot must be added for creosoting.

The life of sleepers is very variable. In some cases they have been known to last 20 years,[1] and in others less than 4. Ten[2] years is, perhaps, a fair average to take, and 20 for the large timbers.

Steel sleepers, 8 feet × 1 foot 4 inches, weighing 150 lbs. each, have been used instead of timber for main lines, but their cost is against them, and they do not make an elastic road for fast traffic.

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[1] *Proc. Inst. C.E.*, xviii. 433.

[2] *Ibid*, xlvi. 147.

For light, narrow-gauge lines, however, they are more suitable. Clips can be pressed out of or, better, riveted to them, and a firm hold given to a rail that has a narrow foot. A sleeper 5 inches wide, ¼ to ⅛ inch thick, and 1 inch deep, 4 feet 6 inches long, costs little more than a wooden one, when the saving in fastenings is taken into account.

**Fastenings.**—Spikes and trenails are generally used to fix chairs to sleepers, but fang bolts are required to securely fasten the clips that are used with T-rails. For very light traffic, dogs are sufficient, but they draw directly the timber begins to fail, and it is generally better to employ clips and fangs.

Fish-plates are made from 18 to 12 inches long. Very deep ones have been tried to strengthen the joint, but, as has been shown above, it is the rail that is weak. Their general dimensions will be gathered from Appendix K. To prevent the bolts working loose, spiral spring washers have been tried, but they are unnecessary.

Detailed estimates are given in Appendix K of the different classes of line that have been considered. The prices of the materials are subject to such variations that they cannot be absolutely relied on, but some idea of the relative costs may be gathered from the figures.

**The Gauge.**—With the ordinary 4-feet 8½-inch gauge there is a play of ¾ inch between the rails and the tyres of the wheels when they are fresh out of the shops, but when they have been running for some time, this is somewhat increased. The gauge on straight lines and easy curves should, therefore, be kept quite tight; indeed, it may be made 4 feet 8¼ inches, or even a little less.

If the gauge be true, a six-wheeled coach, having a wheel base of 18 feet, will go round a curve of 10-chains radius, if the tyres have been newly turned up, and there is no lateral play in the bearings. If the tyres are worn, and there is some play, it will, of course, go round a sharper curve. If the gauge be made ¾ inch slack, which is as much as can be allowed to give the wheels a fair bearing on the rail, the coach will go round a curve of 5-chains radius, or less, if the tyres are worn and the bearings slack.

At the heels of switches the gauge should be kept a little wide; but at the points it should be tight, as also it should be amongst crossings.

**Cant.**—In order to counteract the centrifugal force round a curve, it is usual to elevate the outer rail a certain amount, although the neglect of this is not generally in itself an element of danger. To calculate the amount of cant that should be given, it is necessary to proceed in the following way:—

Let **F** and **W** (Fig. 37) represent respectively the centrifugal force and weight on any axle, and let **R** be the resistance at right angles to the plane of the rails, and $\theta$ the inclination of the latter to the horizon.

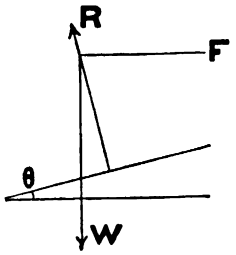


FIG. 37.

By resolving at right angles to the direction of **R**, we get—

$$W \sin \theta = F \cos \theta$$

$$\text{or } \tan \theta = \frac{F}{W} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

Now, by the principles of mechanics—

$$F = \frac{Wv^2}{gr} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

where $v$ is the velocity in feet per second, $r$ the radius in feet, and $g$ the accelerating force of gravity in feet per second, *i.e.* about 32.

$$\left.\begin{array}{l}\text{Hence, by substituting the value}\\ \text{of F in (1), we obtain}\end{array}\right\} \tan \theta = \frac{v^2}{gr}$$

and putting K for the cant and $b$ for the gauge—

$$K = b \tan \theta$$

$$= \frac{bv^2}{32r} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

For the 4-feet 8½-inch gauge $b$ is approximately 5 feet, the distance between the centres of the rails; hence for this gauge—

$$K = \frac{10}{r}\left(\frac{v}{8}\right)^2 \text{ feet} = \frac{120}{r}\left(\frac{v}{8}\right)^2 \text{ inches}$$

For a radius of 10 chains $r = 660$ feet;

$$\text{so } K = \tfrac{120}{660}\left(\frac{v}{8}\right)^2 = \tfrac{2}{11}\left(\frac{v}{8}\right)^2$$

inches

For a speed of 15 miles an hour $v = 22$, so $K = \frac{2}{11}(\frac{11}{4})^2 =$ 1·37

„ 20 „ „ $v = \frac{88}{3}$, „ $K = \frac{2}{11}(\frac{11}{3})^2 =$ 2·44

„ 30 „ „ $v = 44$, „ $K = \frac{2}{11}(\frac{11}{2})^2 =$ 5·50

„ 45 „ „ $v = 66$, „ $K = \frac{2}{11}(\frac{33}{4})^2 =$ 12·37

Hence we have the following table:—

AMOUNT OF CANT IN INCHES FOR THE 4-FOOT 8½-INCH GAUGE.

| Radius in chains. | 5 | 10 | 20 | 30 | 40 | 60 | 80 |
|---|---|---|---|---|---|---|---|
| 15 miles an hour | 2·75 | 1·37 | 0·68 | 0·46 | 0·34 | 0·23 | 0·17 |
| 20 " " | — | 2·44 | 1·22 | 0·81 | 0·61 | 0·40 | 0·30 |
| 30 " " | — | — | 2·75 | 1·83 | 1·37 | 0·91 | 0·68 |
| 45 " " | — | — | — | 4·12 | 3·09 | 2·06 | 1·54 |

The speed should not exceed 15 miles an hour on a 5-chain curve or 30 miles an hour on a 20-chain curve, so that a cant of 3 inches is generally sufficient for all curves. If the speed for all curves over 20 chains radius is limited to, say, 30 miles an hour, the necessary cant can be found by measuring the versine of a chord of given length. To find the length of this chord, we have—

$$r^2 = (r - V)^2 + C^2$$

where V is the versine, and C half the chord;

$$\text{so } r = \frac{V^2 + C^2}{2V} = \frac{C^2}{2V}$$

since $V^2$ is very small as compared with $C^2$;

(3) thus becomes $$K = \frac{bv^2V}{16C^2} = bV\left(\frac{v}{4C}\right)^2$$

Putting K = V, we get
$$\begin{aligned} (4C)^2 &= bv^2 = 5 \times 44^2 \\ \text{and } C &= 11\sqrt{5} = 24{\cdot}5 \\ \text{and } 2C &= 49 \end{aligned}$$

Hence the versine of a chord 49 feet long gives the cant for a speed of 30 miles an hour, and a chord of double this length the cant for double the speed.

**Junction Work.**—The angles and positions of points and crossings may be obtained, (1) by calculation, (2) by measuring from an accurate plan drawn to a large scale, and (3) by setting out the junctions on the ground.

Each of these methods is best under certain circumstances; the first is commonly employed for simple curves, the second for complicated work and in conjunction with the first, and the last only when new work has to be fitted into old.

From Fig. 10 it will be seen, in considering the triangle OB*f*, that—

$$r^2 = (r - v)^2 + c^2$$

$$\text{and so that } v = \frac{v^2 + c^2}{2r} \quad = \frac{c^2}{2r}$$

where *r* is the radius OB, *v* the versine, and *c* half the chord B*f*, since for all railway curves *v* is very small when compared with *c*, and therefore $v^2$ may be neglected.

Thus we get by substituting as in Fig. 38—

$$g = \frac{\mathrm{T}^2}{2r} \text{ in feet} = \frac{6\mathrm{T}^2}{r} \text{ in inches}$$

$$\text{and } 4\tfrac{1}{2} \text{ inches} = \tfrac{3}{8} \text{ feet} \quad = \frac{t^2}{2r}$$

*r* and T being in feet and *g* being the offset at the end of the tangent T; *g* therefore being equal to *v* and T to *c* in the above.

This fixes the lengths *t* and **T** (Fig. 38), *i.e.* the distances from the tangent point to the heel of the switches, and to the centre of the crossing if the radius gauge and opening at the heel of the switches are all given.

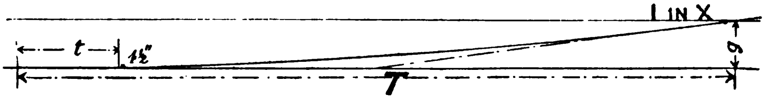


FIG. 38.

Let 1 in X be the angle of the crossing.

$$\begin{aligned}
\text{Then } \mathrm{T} &= 2\mathrm{X}g \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . & (1)\\
\text{and } r &= \frac{\mathrm{T}^2}{2g} = \frac{4\mathrm{X}^2 g^2}{2g} = 2\mathrm{X}^2 g \quad . \; . & (2)\\
\text{so } t &= \sqrt{2r\tfrac{3}{8}} = \sqrt{\tfrac{3}{4}2\mathrm{X}^2 g} = \mathrm{X}\sqrt{\tfrac{3}{2}g} \quad . & (3)\\
\therefore \mathrm{T} - t &= \mathrm{X}(2g - \sqrt{\tfrac{3}{2}g}) = \mathrm{X}(9{\cdot}41 - 2{\cdot}66)\\
&= \mathrm{X} \times 6{\cdot}75 \text{ for the 4-foot } 8\tfrac{1}{2}\text{-inch gauge}
\end{aligned}$$

Any other gauge may be treated in the same way as this, and it may be mentioned that whether the main line be straight or curved, the lead, *i.e.* the distance from the heel of the switch to the centre of the crossing, is always the same. In a simple junction, this lead may, however, be varied a foot or two without injuring the appearance of the curve.

Vehicles with small wheels going through long diamond crossings are liable to take the wrong road, especially if the line they are on is curved. A wheel 3 feet diameter only guards itself a distance of 26 inches, and is thus not safe for an easier angle than 1 in 6, but there is no serious objection to an angle of 1 in 8.

The following table of leads will be found useful:—

| Angle. | Radius when main line is straight. | | | Radius when both lines are equally curved but in opposite directions. | Distance from heel of switch to centre of crossing. | |
|---|---|---|---|---|---|---|
| | feet | in. | chains | | feet | in. |
| 1 in 3 | 84 | 9 | 1·29 | Double the last. | 20 | 3 |
| 1 „ 3½ | 115 | 4 | 1·75 | | 23 | 6 |
| 1 „ 4 | 150 | 8 | 2·28 | | 27 | 0 |
| 1 „ 4½ | 190 | 8 | 2·89 | | 30 | 6 |
| 1 „ 5 | 235 | 5 | 3·57 | | 33 | 9 |
| 1 „ 5½ | 284 | 10 | 4·31 | | 37 | 0 |
| 1 „ 6 | 339 | 0 | 5·14 | | 40 | 6 |
| 1 „ 7 | 461 | 5 | 7·00 | | 47 | 3 |
| 1 „ 8 | 602 | 8 | 9·13 | | 54 | 0 |
| 1 „ 9 | 762 | 9 | 11·55 | | 60 | 9 |
| 1 „ 10 | 941 | 8 | 14·27 | | 67 | 6 |
| 1 „ 11 | 1139 | 5 | 17·25 | | 74 | 3 |
| 1 „ 12 | 1356 | 0 | 20·55 | | 81 | 0 |

Measuring from a plan requires great care; the scale should be at least 8 or 10 feet to an inch, and the lines very fine and accurately drawn.

Setting out on the ground is a long, tedious operation, and should only be used when no other way will do; indeed, it is almost better to make a large scale and very accurate plan, using a well-strained line and steel tape for the base, and a rod for the offsets.

When a junction must be set out on the ground the process is as follows:—

Two pegs are driven in at the point **B** (Fig. 39), one in the centre of the old road, and the other 4½ inches from it for the centre of the new line, these being at the heel of the switches. Another peg is then driven in at the point **A**, 12 feet from **B**, and this is for the point of the switches. A line is then passed by the nails, which have been put in the pegs to mark the centres more exactly, and at 16½ feet an offset is set off with a rule, and another peg put in at **C**, and so on. The first offset is obtained from the formula $O = \frac{6T^2}{r}$, where O is in inches, and T and $r$ in feet. The second and all subsequent offsets are double this, the single offset giving a tangent to the curve.

In setting out a cross-over road, it is necessary to start at both ends, and work to meet, which means going over the work several times.

To measure the angles of the crossings a gauge with marks 6 inches longer and 6 inches shorter than the 4 feet 8½ inches must be provided. The distance between the points, where the centre lines are 4 feet 2½ inches and 5 feet 2½ inches apart, gives the angle of the crossing.

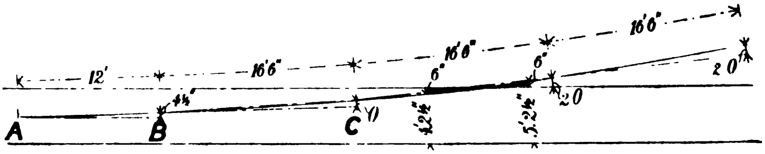


FIG. 39.

In Fig. 40 is given a diagram of a 1 in 6 through double compound crossing, with enlarged views of the switch **A**, crossing **B**, and elbow or diamond **C**. To avoid short closures, the back rails of the latter are lengthened to fit right against the switches; and diamonds should always be made in this way for through crossings, even if compounds or double compounds are not put in at once, in case alterations may be necessary; it is better also always to keep to standard forms. The necessary space between the sleepers carrying the points of the crossings and the switches is a little too much, but the using of 14-inch × 6-inch timbers in place of 10-inch × 5-inch sleepers helps the joint. It would, however, be perhaps better to depart a little from theoretical accuracy, and bring the points a little nearer the crossing, by making the back rails project only a foot instead of 18 inches beyond the tongues.

Before the tongues are placed in the planing machine they must be bent at a point 5 feet 4 inches from the end, so that the

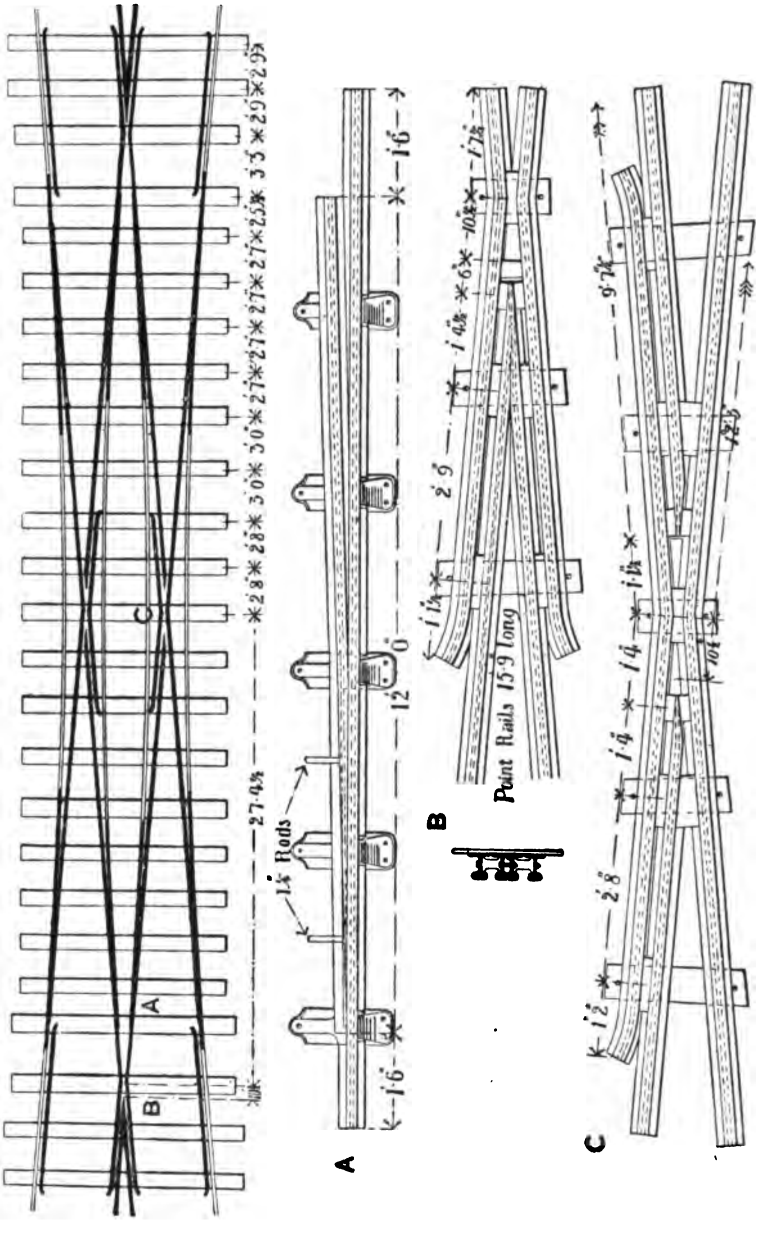

A
B
C
C
27·4⅜
2·8
2·8
3·0
3·0
2·7
2·7
2·7
2·7
2·5⅜
3·5
2·9
2·9
10⅜
1·6
12·0
1·6
1¼ Rods
Point Rails 15·9 long
1·1⅜
2·9
1·4⅜
6
10⅜
1·7⅜
1·2
2·8
1·4
1·4
1·1⅜
10⅜
1·2⅜
9·7⅞

FIG. 40.

points stand out 1¼ inches; and similarly in the case of the points of the crossings and elbows, the rails must be bent at 9 inches from their ends, so that the ends stand out ¾ inch before they are planed, to get the full strength of the rail.

On curves short rails have to be provided to save cutting. Assuming that the outer rail of the curve is laid with 30-foot rails, the inside one must be cut short as follows :—

| Radius. | Length that each rail should be shortened. | Number of 29-foot 9-inch rails per mile. |
|---|---|---|
| chains | inches | |
| 10 | 2·72 | 160 |
| 20 | 1·36 | 80 |
| 30 | 0·91 | 53 |
| 40 | 0·68 | 40 |
| 60 | 0·45 | 27 |
| 80 | 0·34 | 20 |

In laying the line the centre pegs have to be put in again and driven so that their tops may represent rail-level, and the sleepers are then put on the bottom ballast, and the road afterwards raised and packed to its proper height when the top ballast has been partly spread.

A plate is used to give the right expansion at the joints, and a template for boring the sleepers for the spikes, trenails, or fangs, or the holes are bored by machinery when the rail seatings are planed to their proper inclinations, all before creosoting.

A cross-section of a tramway for ordinary tramcars is given on the left-hand side in Fig. 41. To accommodate ordinary rolling stock a wider groove is necessary, as shown on the right-hand side of the figure, and to keep this as narrow as possible the gauge must be reduced to 4 feet 8 inches when the groove need be only 1¼ inches wide.

To accommodate ordinary tramcars a space of 3 feet between the tracks is all that is necessary, but for railway rolling stock another 30 inches must be given. Thus for tramcars the tracks should be 7 feet 9 inches centre to centre, and for railway trucks 10 feet 3 inches at the least.

To get to the clearing point as quickly as possible, both lines of a tramway are usually curved, the one to the right and the other to the left. The opening at the heel of the points being

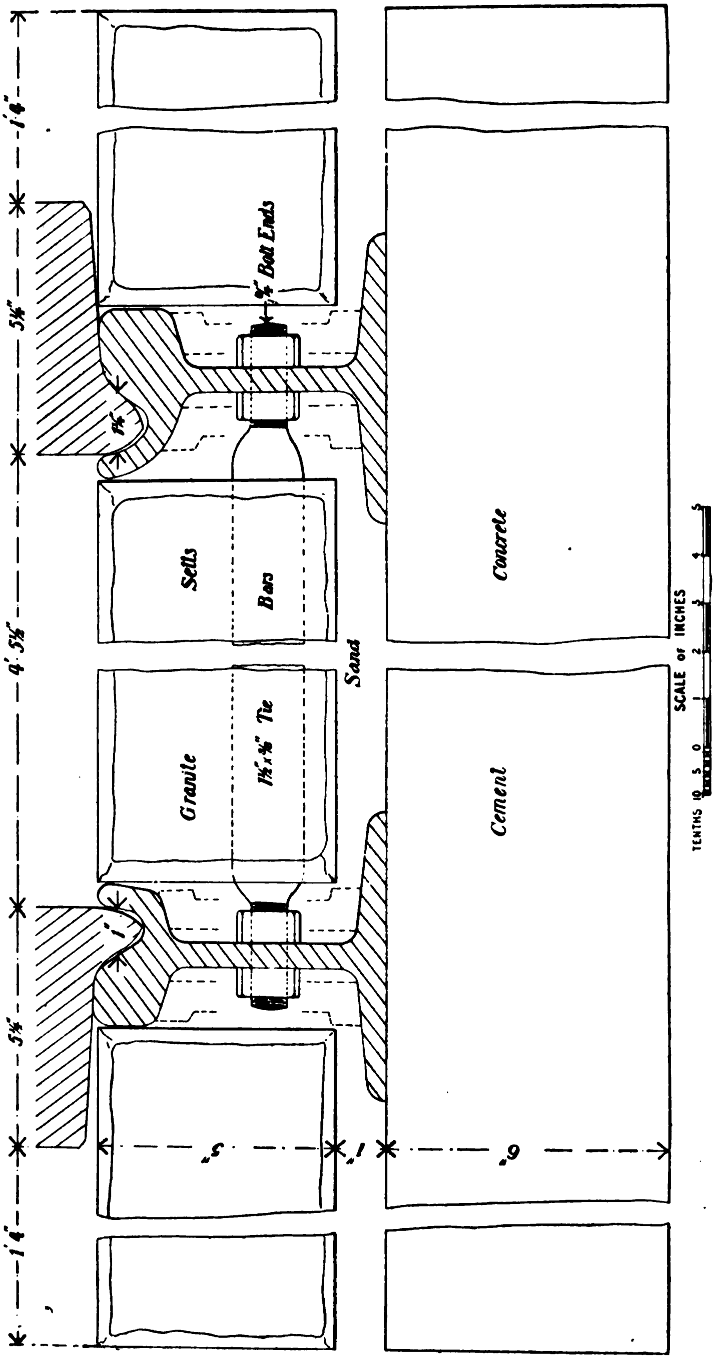

1' 4"
5¼"
4' 5½"
5¼"
1' 4"
¾" Bolt Ends
1¼"
1"
Setts
Bars
Granite
1½" x ⅜" Tie
Sand
Concrete
Cement
5"
1"
6"
SCALE of INCHES
TENTHS 10 5 0 1 2 3 4 5

FIG. 41.

4 inches, the radii of the curves and corresponding angles of the crossings are given by the following table :—

| Angle of crossing. | Radii of curves. | Distances from tangent point. | | Centre of crossing to heel of points. |
|---|---|---|---|---|
| | | To centre of crossing. | To 4-inch opening of points. | |
| | feet | feet in. | feet in. | feet in. |
| 1 in 3 | 168 | 28 0 | 7 6 | 20 6 |
| 1 „ 4 | 300 | 37 4 | 10 0 | 27 4 |
| 1 „ 5 | 467 | 46 8 | 12 6 | 34 2 |
| 1 „ 6 | 672 | 56 0 | 15 0 | 41 0 |

# CHAPTER VIII.

## *BRIDGES AND CULVERTS.*

**Preparation of drawings—Points of importance in the design—Wing walls—String courses and spandrils—Footings, foundations, and dry lining—Minimum structure—Span and headway—Parapets—Retaining walls—Pressure of earth—Greasy clay—Shrinkage of clay—Newels—Coping and caps—Arches—Various designs for common bridges and viaducts—Size of culverts—Rainfall and flow off the ground—Ornament—Design for footbridge—Loads on bridges and foundations—Girders—Setting out—Level peg—Extra foundations—Skew arches.**

It is only proposed to deal in this chapter with the small works that are usually met with on light railways in an easy country. Those who are called upon to design large viaducts and river bridges can refer to Mr. Mill's "Railway Construction" in this series, where they will find a number of examples and some good detailed illustrations. Whatever the size of the structure, however, the principles on which the drawings should be prepared and the work executed are the same.

To design any ordinary road bridge such as is illustrated by Fig. 42, it is necessary to have the following information:—

(1) The width of the road and railway, and the formation width in each case.
(2) The height from the surface of the rails to that of the road, and the rate of inclination of the latter.
(3) The ratio of the slopes of the cutting or bank.
(4) The angle of crossing.
(5) The nature of the foundations and of the backing to the abutments and wings.

In addition it is necessary to have an enlarged plan and sections of the site, with the centre line, approaches, etc., shown thereon, and a note to explain whether the centre line is the centre of the single or of the double line.

The first thing in preparing the drawings is to lay down on the plan the centre lines **HH, KK,** the tops and bottoms of the slopes **LL, MM,** as shown in Fig. 42, and then, the positions of the ends of the wings having been found by trial, the elevations and sections can be proceeded with. On these the formation and existing surface of the ground should be shown, and the reduced level of the former, as well as that of the girder beds, or springings, should be written on. It is not often possible to finish off any one view at once, but all must be kept going together. Unless the circumstances are exceptional, the slopes allowed for are usually 1½ to 1, and the lengths of the wings are made rather more than sufficient for this. Enough elevations and sections should be given for the depths of the foundations to be marked on, when the bridge has been built, the half plans and elevations shown for the purpose of economizing room in Fig. 42 not being sufficient for this purpose. It is generally better to show the brickwork or masonry that is required if the foundations are good, and to make up the extra depths with concrete when bad ground is encountered.

The following points should be attended to:—

(1) The wing walls should be slightly curved on plan, in order that the pressure from behind may tend to straighten them and not produce a curve the wrong way, as it is pretty sure to do if they are built straight, but on the drawings this need not be shown.

(2) The string course should be a few inches higher in the centre than at the ends, for, if quite straight, it would, by an optical illusion, appear to be lower in the centre, as if it had sunk.

(3) The finished slopes, whether of bank or cutting, should end a foot or so behind the back of the coping of the wings.

(4) The backing to the arch above the skew-back may be of lime concrete; but for concrete abutments and wings, whether faced with brickwork or not, it is better to use cement concrete.

(5) Each footing in the case of brickwork should be 6 inches high, and project 2¼ inches beyond the one above it. Two, three, or four footings are required, according to the duty of the bridge and the nature of the foundations. The top one should be 6 inches below the surface of the road or the formation of the railway, as the case may be; but, if ballast is cheap and brickwork is dear, it may be a foot below rail-level instead, in the latter case.

(6) Bridges and culverts under heavy banks should be kept a

ARCHED BRIDGE OVER RAILWAY

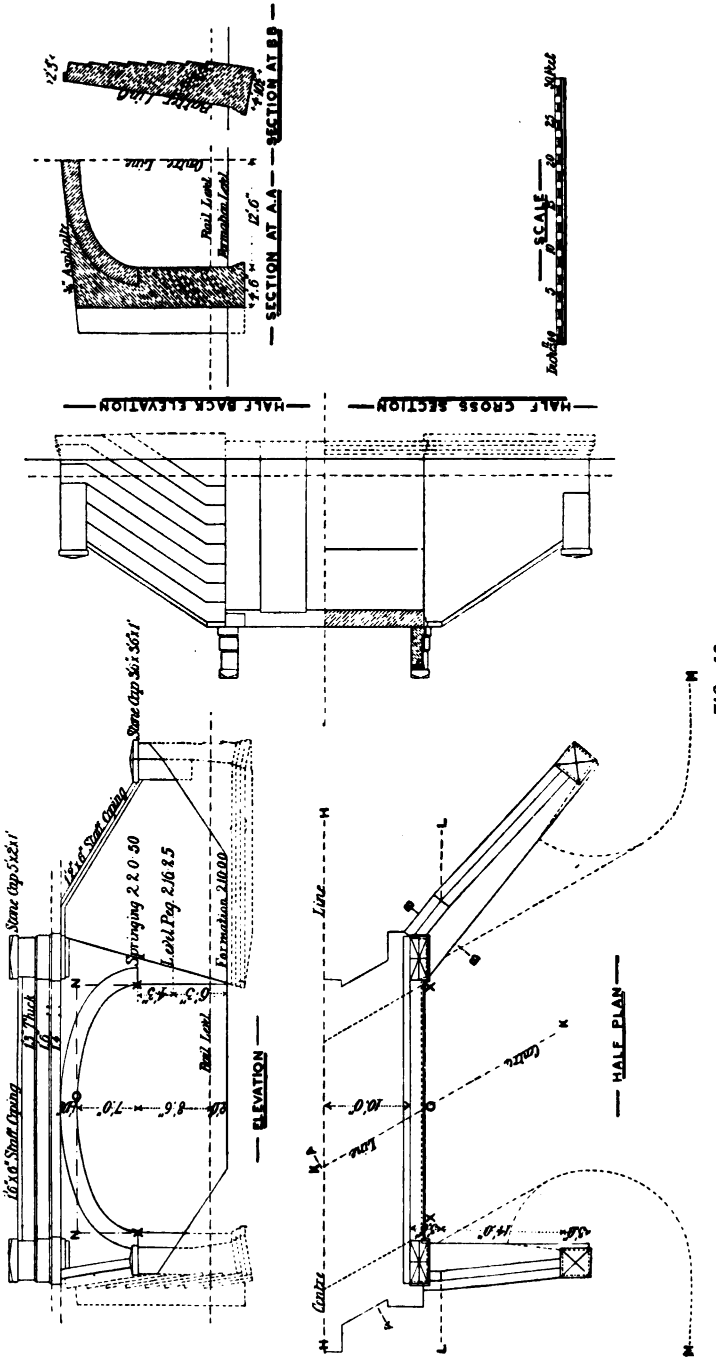


FIG. 42.

little higher at the centre of the bank than at the ends, and should where possible be put well down in the solid ground and strengthened with counterforts.

(7) Unless the foundation is very solid, since the ground on which a heavy bank rests is liable to be compressed at the centre and raised at the sides, the ends of a culvert may actually be lifted; also, unless the culvert is built well down in the solid ground, if the greatest care is not taken when the bank is being tipped, it will be pushed over by the unequal loading when the toe of the bank reaches it.

(8) Care should be taken to prevent water from accumulating behind the walls by lining them with stone and leaving weep-holes; care also must be taken to ram the earth for a width of at least 6 feet to guard against unequal loading during construction.

The loading gauges of the different railway companies vary considerably, but the bridge illustrated in Fig. 42 will take any loads in this country. It is necessary that there should be sufficient height and width for a carriage to pass through with the doors open, so if the rails are 2½ inches wide, the distance between the centres of the two roads must be 11 feet 1½ inches, to give the necessary 6-foot space between the lines, and if the maximum width of a carriage with the doors open, including the handles, is 13 feet 3 inches, the total minimum width between the abutments must be 24 feet 4½ inches, or, allowing for the cant curves, etc., say, 25 feet, from 2 feet 6 inches to 10 feet 6 inches above rail-level.[1]

The following table gives the minimum heights and depths from the surface of the road to rail-level in different cases:—

BRIDGES UNDER THE RAILWAY.

| Description. | Headway. | Height, road to rail. | |
|---|---|---|---|
| | | feet | in. |
| Public road, arch, 25-foot span | 15 feet at centre . . . . . . . | 19 | 0 |
| „ „ „ „ | 15 „ for a width of 10 feet . . | 19 | 6 |
| „ girders, „ „ | 15 „ for the whole width . . . | 17 | 0 |
| „ troughs, „ „ | 15 „ „ „ . . . | 16 | 4 |
| Private road, arch, 12-foot span | 14 „ at centre . . . . . . | 17 | 6 |
| „ girders, „ „ | 14 „ for the whole width . . . | 16 | 0 |
| „ troughs, „ „ | 14 „ „ „ . . . | 15 | 0 |

---

[1] *Proc. Inst. C.E.*, cii. 260.

BRIDGES OVER THE RAILWAY.

| Description. | Headway. | Height, road to rail. feet in. |
|---|---|---|
| Arch, 14-foot span . . . . | 14 feet 6 inches at centre . . . | 17 0 |
| „ 25-foot „ . . . . | 15 „ 6 „ „ . . . | 18 6 |
| Girders, „ „ . . . . | 14 „ 6 „ for the whole width | 17 0 |
| Troughs, „ „ . . . . . | 14 „ 6 „ „ „ | 16 0 |

It is stated in the Railway Clauses Act that the springing should be 12 feet above the road-level, but this is rarely adhered to. Up to a height of 2 feet 6 inches above rail-level a width of 10 feet for a single-line bridge is sufficient; from this level to the top of the carriage doors, *i.e.* to 10 feet 6 inches above rail-level, the width should be 14 feet, or for a double line 25 feet, for ordinary rolling stock.

Parapets for over-bridges should be 4 feet high and 14 inches, or better, 18 inches, thick, if of brickwork; if of masonry, they should be rather more. If they are made 18 inches thick they may be panelled.

A batter of 1 in 6 does well for wing walls. A thickness of 2 feet 3 inches at the top, with a vertical face at the back, gives a wall thick enough for most cases; 1 foot 10½ inches is often enough, but for very heavy ground 2 feet 7½ inches, or even more, is necessary, especially with surcharged walls. Retaining walls need not be made more than half as thick as theory dictates. With a good foundation and good backing the thickness need only be one-fourth the height, and under no conditions of surcharge or bad backing need it be more than one-half.[1] The force exerted by coal is equal to that of a fluid weighing 6 lbs. per cubic foot; of granite metal, of 10 lbs.; of sand, of 15 lbs.; and of loose earth, of 20 lbs.; the extreme case being an actual fluid of salt water weighing 64 lbs. per cubic foot. More walls fail by sliding forward than by overturning, so that a greasy foundation is to be avoided. Cracks are sometimes caused by the shrinking of clay in dry weather, and so it is sometimes advisable to cover a clay bottom with dry gravel before concreting, to prevent the contraction of the clay tearing the concrete to pieces.

Newels should be from 2 feet 3 inches to 3 feet square and 4 feet high, so that the fences can be made good to them.

[1] *Proc. Inst. C.E.*, lxv. 140.

Staffordshire blue bricks, 14 inches × 6 inches, make perhaps the best coping, and York stone is one of the best materials for the caps. A projection beyond the brickwork of about 3 inches should be given to these, and a throating made all round.

Arches of 14-foot span should be 18 inches thick; of 25-foot span, 1 foot 10½ inches; of 35-foot span, 2 feet 3 inches; of 40-foot span, 2 feet 7½ inches; and of 50-foot span, 3 feet thick. In the last two cases they may be a little thinner in the centre, say, 2 feet 3 inches and 2 feet 7½ inches respectively, for a width of 15 or 20 feet.

Large span bridges should have relieving arches in the spandrils, especially when one side is higher than the other. The spandrils of the bridge shown in Fig. 43 may be solid so long as the inclination of the road is not greater than 1 in 30; but if the road rises on one side and falls on the other at a faster rate than this, relieving arches must be introduced on the high side, or the arch will not be in equilibrium.

If a bridge over the railway is to be built in a cutting more than 15 feet deep, it is generally the most economical mode of construction to put the wings at right angles to the abutments, as in Fig. 44, if a good foundation can be got near the surface. If the cutting is less than this in depth, it is better to turn them off at an angle of 45°, as in Fig. 42. If there is no cutting at all, but a raised approach, it is perhaps the cheapest thing to make them nearly parallel to the abutments, as in Fig. 45, although in this case they do not make such good counterforts to the latter.

The different designs that can be adopted may be divided into five classes as follows:—

(1) Single 25-foot spans with abutments and wings (Fig. 42).
(2) Three or more spans (Fig. 44).
(3) Tunnel bridges with the extrados of the arch some distance below the formation level of the road or railway (Fig. 45).
(4) Flying arches springing off the slopes (Fig. 43).
(5) Girders.

The main circumstances which influence the design are the depth of the cutting or height of the bank, the material it is composed of, and the consequent slopes necessary, the width of the roadway, the angle of skew, and the comparative prices for the work.

Under ordinary circumstances it will be found that, in the case of a bridge over the railway, where the height from the ground to the rails is 17 feet, or where the roadway has to be raised, the cost of an arch is very nearly the same as that of a girder top, for, although the arch itself costs much less than the ironwork,

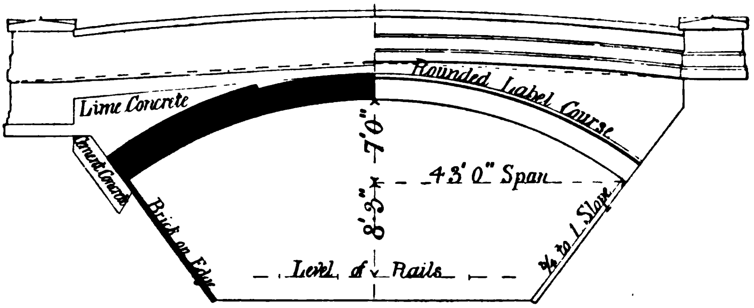


FIG. 43.

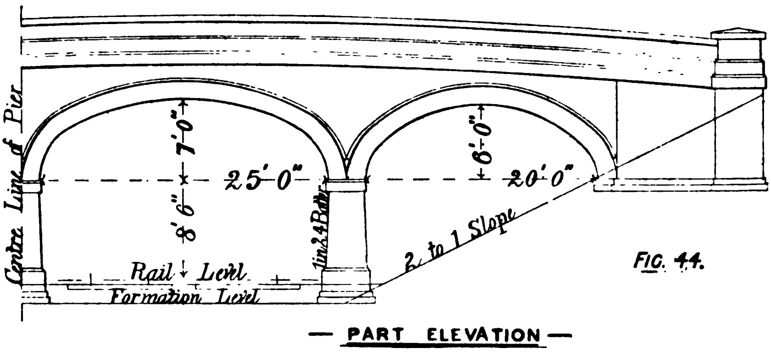


FIG. 44.

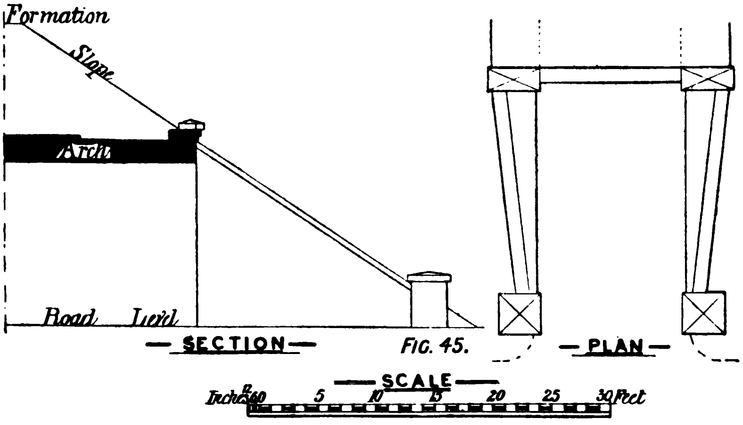


FIG. 45.

there is a saving in the quantity of the brickwork in the girder bridge, owing to the diminished height of the abutments and wings. As there is a reduction of at least 18 inches in the height of the approaches in the latter, it is in most cases more economical as regards first cost to employ girders, but the question of maintenance has to be considered.

With under-bridges of not more than 35-foot span there is usually also not much difference in the cost of an arched and of a girder bridge, the saving in the latter case being as before in the metal and earthwork in the sunk approach.

Except for large spans, and in the neighbourhood of mines, girders are not applicable when the cuttings and banks are more than 20 feet deep.

In a 20 or 25-foot cutting it is not economical to employ a flying arch, whatever the width may be. If the cutting is through chalk or rock, the best construction is a 25-foot span, with the abutments and wings only thick enough to protect the sides of the cutting from the weather.

In a clay cutting where the slopes are 2 to 1 or more, a three-arched bridge is better if the width is not more than 25 feet.

In a 30-foot rock cutting, if the width is not more than 20 feet, a flying arch should generally be employed; if it is more than this, a 25-foot span arched bridge and thin facing is better.

Tunnel bridges are not often used in cuttings, but under banks 30 or 40 feet high they are generally better than three spans.

With banks 20 or 25 feet in height single-span bridges are almost universal.

Fig. 46 illustrates the trough girder construction, which is very economical as regards headway. Each rail is here carried in a trough, which is made up of one bottom plate, two webs, four angle and two **T**-irons.

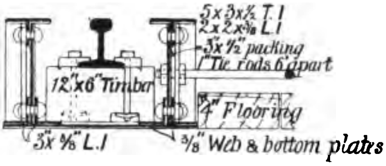


*FIG. 46.*

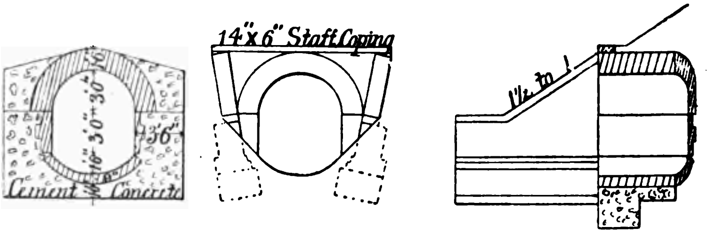
Viaducts should be built on similar lines to the bridge illustrated in Fig. 44, and the piers should batter at about 1 in 24 each way. For 50-foot spans the arches, if semi-circular, should be 2 feet 7½ inches thick, and consequently the piers at spring-level should be 5 feet 3 inches wide.

With a 1 in 24 batter it is unnecessary to use specially moulded bricks. In preparing the plans for a high viaduct, it must be remembered that, to show at all, the string, plinth, and coping of the parapet must be very bold, for what may look very well on paper will become dwarfed in reality by the distance.

If a viaduct is on a curve the piers are usually taper, and the arches parallel on plan.

Two-foot and 3-foot culverts are usually made circular, with 9 inches of brickwork all round, and wings at right angles to their barrels. Fig. 47 is a design for a 6-foot culvert with its wings the other way. It will be seen that the wings have here been set back far enough for the whole arch to be seen. Attention to such details is necessary to avoid a slovenly appearance. On one side the section the brick facing to the concrete wall is shown as 9 inches and 14 inches thick alternately, and on the other 4½ inches and 9 inches which is all that is really required.

In fixing the dimensions of culverts, allowance should be made for a flow of water off the land equal to from ½ inch of rain over the drainage area in flat lands to 3 inches or even more in hilly country in twenty-four hours.



—SECTION— —ELEVATION— —LONGITUDINAL SECTION—

FIG. 47.

In the Fen district a fall of 2 or 3 inches of rain in a day only produces a flood equal to ½ inch, and ¼ inch is usually allowed for in designing the main drains.[1]

In Ireland a flood of from ⅜ to 1 inch has been allowed for, according as the ground is flat or hilly.[2]

In the Manchester district floods equal to from 3 to 9 inches of rain have occurred, or greater than the actual rainfall.[3]

In India floods of 3 inches have been recorded.[4]

It is not often possible, without largely increasing the cost, to make really beautiful railway bridges, but some care should be taken to make them as inoffensive in appearance as possible.

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[1] *Min. Inst. C.E.*, xlv., 79; and lxvii. 223.

[2] *Ibid.*, lix. 265.

[3] *Ibid.*, lxvii. 255.

[4] *Ibid.*, lxxx. 205.

Well-proportioned parapets and newels will do a good deal towards this, and an arch as a rule looks better than a girder top, and, although it often costs more to construct, when once built it is practically done with, and does not require constant painting.

Bold flying arches always look better than 25-foot spans, and good projecting strings, with plinth and dentil courses, pay well for their very slight extra cost.

Pilasters should be longer than they are high, and are improved by panels, especially if a different coloured brick is used in these. In an arch for real effect a pointed parabola should be used in preference to an ellipse, although this curve is a little unscientific. All recesses should be deep, and all trumpery ornament avoided.

In Fig. 48 is given an elevation of a footbridge, which is more suitable for its work than the ugly angular girders so often seen.

The usual loads on bridges and the pressures that may be put on various foundations are given in the following table, which has been compiled from the author's work on "Structural Mechanics":—

| | | |
|---|---|---|
| Pressure of wind at an angle of 30° to the horizon, | | 56 lbs. per square foot |
| Metalling and ballast, | | 1¼ cwt. „ cubic „ |
| Permanent way, single line, | | 1 „ „ lineal „ |
| Roadway bridges, moving load, | | 1 „ „ square „ |
| „ „ concentrated load on 12 feet by 6 feet area, | | 20 tons |
| Railway bridges (single line, for heavy engines) | 10 to 20 foot span, | 3·5 to 2·3 tons per foot run |
| | 20 to 40 „ | 2·3 „ 1·8 „ „ |
| „ „ „ | 40 „ 55 „ | 1·8 „ 1·6 „ „ |
| „ „ „ | above 55 „ | 1·6 „ „ |
| Safe resistance of rock in foundations, | | 13 tons per square foot[1] |
| „ „ chalk, | | 4 „ „ |
| „ „ close sand or gravel, | | 5 „ „[2] |
| „ „ solid blue clay or gravel, | | 3 „ „ |
| „ „ London clay, | | 2 „ „ |
| „ „ 12 in. × 12 in. piles well driven, | | 20 „ „ |

The following formulæ will be found useful in making the necessary calculations for girder and other bridges:—

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[1] *Proc. Inst. C.E.*, lxi. 192.

[2] *Ibid.*, l. 112.

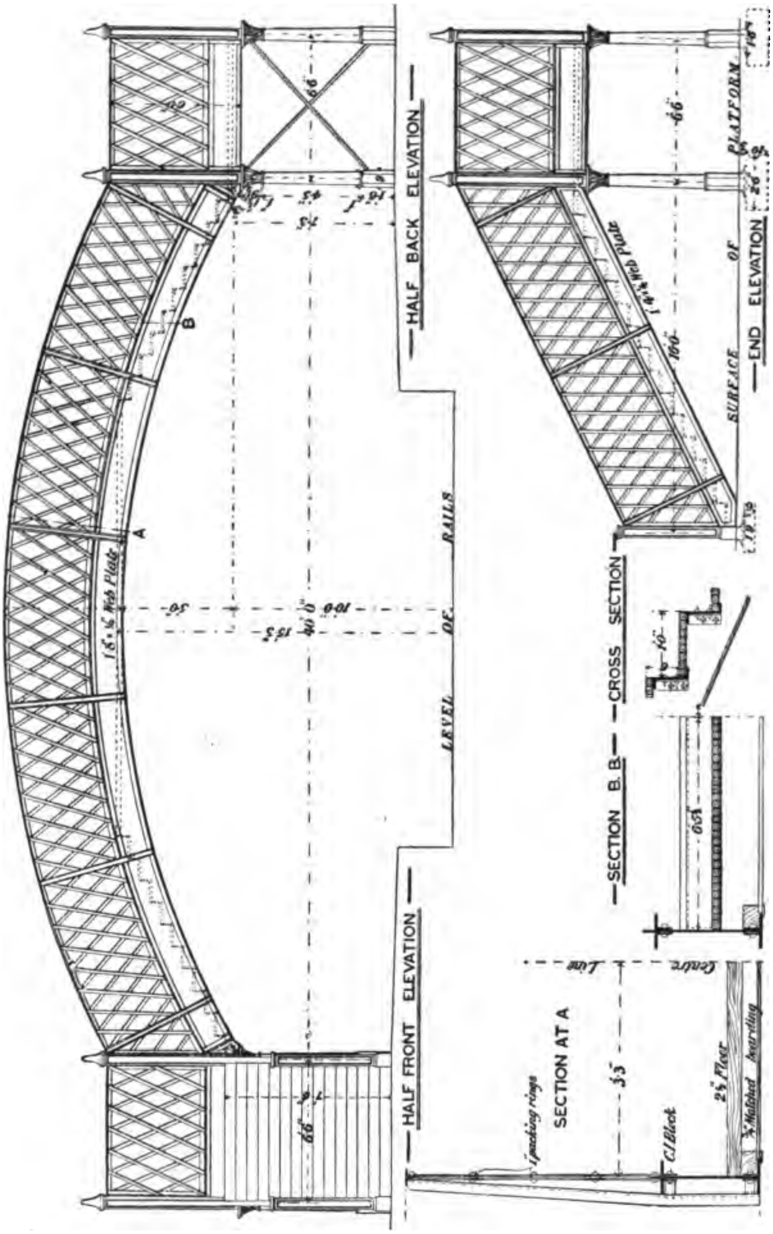
HALF BACK ELEVATION
HALF FRONT ELEVATION
END ELEVATION
CROSS SECTION
SECTION B.B.
SECTION AT A
LEVEL OF RAILS
SURFACE OF PLATFORM
1'8" × ⅜" Web Plate
1'4" × ⅜" Web Plate
A
B
40'0"
15'3"
10'6"
6'6"
Packing rings
C.I. Block
2½" Floor
¾" Matched boarding
Centre Line

FIG. 48.

$$a = \frac{wl^2}{8sd} = \frac{\mathrm{WL}}{4sd} : \mathrm{W} = \frac{bh^2}{36l} \text{ for fir, and } = \frac{bh^2}{24l} \text{ for oak}$$

where $a$ is the sectional area of either flange in square inches ;
$w$ „ load per foot run in tons;
$d$ „ depth in feet between the flanges of the girder;
$s$ „ safe resistance of the metal, *i.e.* 4 or 5 tons per square inch for iron and $6\frac{1}{2}$ tons for steel;
$\mathrm{W}$ „ load at the centre in tons;
$b$ „ breadth of a solid rectangular beam in inches;
$h$ „ depth „ „ „ „
$l$ „ span in feet.

In designing girders it is necessary to make due allowance for corrosion. The thickness of the web depends on the number of rivets which can be got into it to resist the shearing strain at the joints, but it should never be less than $\frac{3}{8}$ inch. The web should be stiffened about every 3 feet by **T**-irons or angle irons and gusset plates. The width of the flanges should not be less than one-thirtieth the span to prevent buckling, unless overhead or side bracing is introduced, and the cross-girders should rest as near the centre of the main girders as possible for the same reason. Provision should be made for expansion and access given to all parts for the painters.

In setting out a bridge the first operation is to pick up the centre line of the railway for some distance each side. It is unwise to take only a few pegs, as some of them may have been moved, and in the case of a long straight line it is especially necessary to be careful to get the true direction. Next, the point of intersection of the centre line of the road and that of the railway having been fixed, a tangent to the curve, if the line is curved, must be laid off, and two pegs with nails in them, one near and one some distance away, must be driven on each side, the second and more distant pegs being for the purpose of acting as keepers to check the neat work, and to save time in the event of some of the other pegs being lost.

Two lines are then attached to the nails on the pegs, one representing the centre of the railway and the other that of the road, and the setting out of the foundations may be proceeded with from a sketch which the assistant engineer will have made in his book for the special purpose of the foundations, an allowance of

2 feet 6 inches having been given in front of the neat work to give the bricklayers room to get at the face, no allowance in front of the footings or at the back being of course necessary.

All the steps in the wings must be accurately set out to save the necessity of making alterations in the drawings.

To give the level, a peg must be put in and its height above datum found (Fig. 42). The depth from this peg to the foundation, girder-bed springing, or other definite point must be given to the excavators and bricklayers.

As errors so easily creep in, it is advisable to go at any rate roughly over the setting out a second time, to see that no mistake has been made before it is too late.

To lay down the lines on the centre for a skew arch, it is necessary to erect profiles at the quoins **XX** (Fig. 42), and to stretch a horizontal line, **NN**, between them. From this face-line the points in the curve may be obtained by plumbing down every few feet, using a thin straight-edge to draw the curve from point to point. From the middle point **O** a line may then be drawn at right angles by using a long thin spline which is quite straight, and from this the parallel courses can be set off.

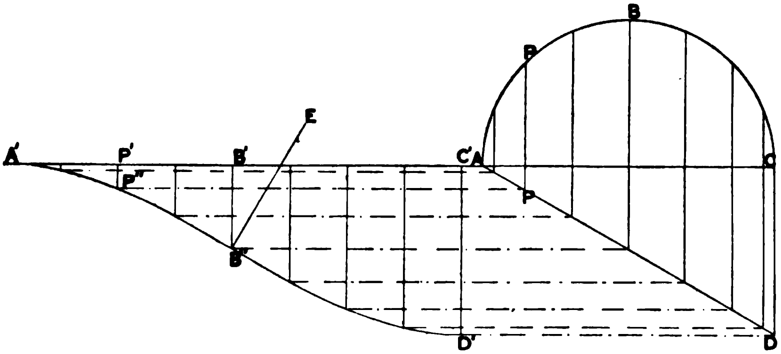

FIG. 49.

The development of a skew arch can be drawn in the following way:—

Let **AC** be the square span of the semicircular arch **ABC** in Fig. 49, and **AD** the face-line.

Produce **AC**, and make **A'C'** equal to the curve **ABC**.

Take any point **P**, make **A'P'** equal to the curve **AP**. Draw **PP** at right angles to **AC** and **PP''** parallel to **AC**, intersecting the perpendicular **P′P″** in **P″**, which is therefore a point on the curve.

Strictly speaking, the courses should all be at right angles to the face-line, but they are generally made parallel to the central course. In long tunnel bridges with skew faces it is common to curve the courses at the ends so that the faces may be correctly built, but to construct the central portion like a square bridge.

# CHAPTER IX.

## *TUNNELS AND COVERED WAYS.*

**Greatest economical depth for a cutting—Comparative cost of single and double line tunnels—Form and thickness of lining—Setting out—Construction of shafts and tunnel—Timbering—Needles—Iron tunnels on Greathead's system—Shields—Compressed air—References to works.**

When the formation level is more than a certain depth below the surface, economy can be effected by substituting a tunnel for open cutting. What this depth is depends on a variety of circumstances, of which the following are some of the chief:—

(1) The cost of land and excavation per unit; in towns where land is valuable a very shallow cutting being often more expensive than a tunnel or covered way.

(2) The nature of the strata and general contour of the ground, the former of which influences the slopes of the cutting and the cost of the repairs to the slips that are likely to occur, and also the cost of the tunnel, which may require more or less timbering, brickwork, pumping, etc.; while the contour of the ground may be such that, if a tunnel is adopted, the general level of the line may be so lowered as to avoid high banks and viaducts without greatly increasing the lengths of the cuttings.

(3) The character of the line and whether it is single or double, a single-line tunnel under ordinary circumstances costing little more than half one for a double line.

A cutting 60 feet deep with 2 to 1 slopes requires a width of 240 feet more land than a tunnel, or about a sixtieth part of an acre per lineal yard. It would contain about 1000 cubic yards of excavation for a double line, and might perhaps require 100 cubic yards of burnt ballast to repair slips, and it is fair to assume that bridges costing £1000 each would occur every 10 chains. The cost per lineal yard would therefore be as follows:—

| | | £ |
|---|---|---|
| Land, $\frac{1}{60}$ acre | at £600 per acre | 10 |
| Excavation, 1000 yards | „ 1s. per yard . | 50 |
| Burning clay, 100 „ | „ 3s. „ „ . | 15 |
| Bridges . . . . . . . . . . . . . | | 5 |
| | | 80 |

Now, £70 per lineal yard is a very fair price for a double-line tunnel, so that in this case it would appear to be economy to adopt the tunnel without considering the saving which might be achieved by reducing the height of the banks, both with regard to the cost of the land and to the saving in repairs to the slips which are likely to occur.

The determination of the exact depth, when it becomes better to adopt a tunnel, is a matter requiring a considerable amount of experience and a full investigation of all the circumstances of the case, and no hard-and-fast rule can be given.

Double and even single line tunnels do not often occur on a light railway, but this work would be incomplete without some reference to them, and the iron subways recently constructed in London bear the same relation to the older metropolitan lines as a light railway in the country does to a main line.

If the railway is being made for a single line, it is nearly always better to make the tunnel for a single line also; although when the second line is constructed the formation width at its ends will be much increased, it being necessary to have a space at the very least of 12 feet here between the lines instead of the standard 6 feet. The length of the extra width of the cutting depends on the curves of the line, and may be reduced by curving the ends of the tunnel, and this, by putting the tunnels further apart a little way in from the face, will be an advantage during construction, as it will reduce the risk of accident to the one first constructed. In all, or nearly all, cases two single-line tunnels cost more than a double one, but the difference is not very great, and varies with the material cut through.

By comparing the cross-sections given in Figs. 50 and 51, it will be found that there are some 80 cubic yards of excavation and 21 cubic yards of brickwork per lineal yard in the one as against 40 cubic yards of excavation and 10 cubic yards of brickwork in the other, the price per cubic yard being higher, however, in the latter case.

The necessary thickness of the lining and the form of cross-section depend on the nature of the ground cut through. In some cases through solid rock no lining at all is required, but this is very rare, and in many instances, where the lining has been dispensed with in the first instance, it has had to be afterwards added at a greatly increased cost, when the traffic was running. Where the strata is of a chalky or rocky nature the lining has little more to do than carry itself, its duty being simply to protect the sides and roof from exposure to the weather, or to prevent fragments falling from the top. Hence in the case of a double line three, or perhaps four, rings of brickwork are quite sufficient, and for a single line two rings, the arch being semicircular and the side walls vertical in each case.

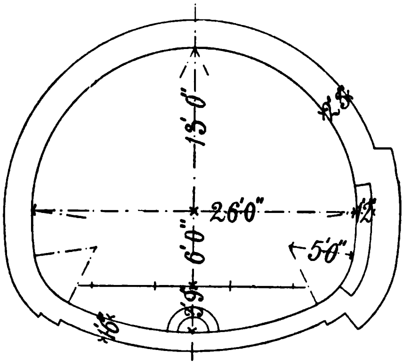

FIG. 50.

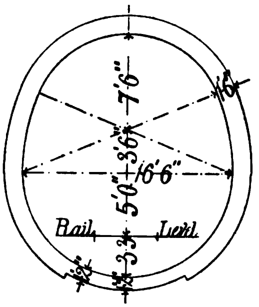

FIG. 51.

On the other hand, in the London clay an enormous pressure has to be resisted, chiefly owing to the property which the clay has of swelling when exposed to atmospheric influences. The section which has been found most suitable for resisting this pressure is almost a perfect circle with 6 rings of brickwork all round for a double line and 4 for a single line.

In the ground more commonly met with, the most suitable form is a semicircular arch with curved side walls and an invert, as in Figs. 50 and 51. The thickness of the arch and side walls is generally 6 rings and of the invert 4 rings.

In the old tunnels a large space was provided above the trains for the smoke and foul air, but this is not now considered necessary, and the roof is brought much lower.

Rather more width is necessary in a tunnel than a bridge for the storage of materials when the platelayers are at work, and manholes, 14 inches deep, 3 feet 6 inches wide, must be provided on each side, 66 feet apart, for the safety of the men.

Where heavy buildings rested on the arch of the Metropolitan Railway, it was assumed that the part of the arch carrying a wall was equal in width to twice the thickness of the wall plus twice the thickness of the arch.

In setting out a tunnel, it is generally necessary to build one or more observatories, on which the theodolite can be fixed so as to command the shafts. The instrument, having first been tested to prove that it reverses properly, is placed on the observatory and set exactly on the centre point, which has previously been carefully plumbed up from the ground or fixed by the theodolite. The instrument is then directed to a distant pole, which is put up on the centre line at a point where a permanent peg has been driven, in such a position that it cannot be disturbed. Two wires are next hung down the shaft with about 10-lb. weights to keep them vertical, each hanging in a bucket of water. The furthest of these is first fixed truly in line by the theodolite, and afterwards the nearer one, the other being meanwhile covered from view by a board. The board is then removed, and the two wires should appear as one, or, if they do not, one or other must be moved until the lining is perfect. The theodolite is next taken below and set up in line with the wires—a somewhat tedious operation, unless a horizontal motion is provided in the instrument. The line may now be transferred to the byotts, or cross-timbers, and fixed on them by nails, from which candles can be hung to direct the miners, and by means of which the side invert moulds can be set. These centres must be checked several times to save all chance of error, and with proper care this may be confined to an inch or two in 10 chains.

In setting out the Mersey tunnel the shafts were not on the centre line, but an angle had to be turned off when the heading reached the centre, the distance being measured off by a steel tape. A large number of observations were made and the mean taken, and the error at meeting was very small. German silver wires $\frac{1}{40}$-inch diameter with 33-lb. weights were used, and the wires were moved into position horizontally by fine threaded screws. To see if they were hanging freely, an electric battery was connected with them, and if the galvanometer moved and so showed that the circuit was complete, it was clear that the wires were touching something, and so were not hanging freely.

It will sometimes be found a good plan to have the near wire black while the far one is bright, for by this means it can be more readily seen when the one is covering the other.[1]

For the Brighton outfall sewer galvanized steel wires were employed, with weights of sheet lead bent in the form of six-pointed stars on plan for the purpose of steadying them from horizontal motion and twisting when they were hung in the water-buckets. In this case, also, the shafts were frequently not on the centre line, but by repeating the angles great accuracy was obtained. The instrument was set up on the centre line, and, the wires having been ranged truly in line at the shaft, the angle between this line and the centre line was obtained, and the distance from the instrument to the nearest wire measured. The instrument was then taken below, and set up truly in line with the wires at the same distance from them, and the same angle set off as was taken above ground. To make the wires visible, black boards behind them when they were white, and white boards when the wires were black, were employed.[2]

In sighting above ground for the long tunnel on the Dore-Chinley Railway, a vertical black board with a white line 3 inches wide down the centre, plumbed like a bricklayer's plumb-rule and fixed by guy-ropes, was employed successfully at a distance of 3 miles, and a black tube centred on a plumb-line could be seen against the sky nearly as far off.[3]

The pier on which the theodolite rests must, of course, be quite clear of the building and roof over it, and also of the platform on which the observer stands.

The levels are usually transferred down the shafts by a steel tape, and must, of course, be carefully checked. In the case of the Mersey tunnel, it was not possible to level across the river on the site, and to have got the level at all would have entailed going many miles up it and down again, so a mean of a large number of ordnance bench marks each side was taken, and there was no error at meeting.

The first operation in actual construction is the sinking of the shafts. These are usually about 9 feet diameter, with 9 inches of brickwork in the case of permanent shafts, and 9 feet square if only temporary and of timber. In constructing the brick shafts, a depth of about 8 feet is excavated, and an oak kerb, consisting of two thicknesses of 2-inch oak planks breaking joint and tied together with ¾-inch bolts, is laid upon two 9-inch × 6-inch oak bearers each 1 foot from the side of the shaft, and these bearers are suspended by 1½-inch rods to 14-inch × 14-inch timbers about 30 feet long, resting in their turn on transverse bearers at their ends. The next length is constructed in the same way, the rods being attached to the oak bearers next above them. The brickwork is carried down to the top of the intended arch of the tunnel, the part below this level being timbered only. Permanent shafts for ventilators should be put about ¼ mile apart, or nearer in a very wet tunnel. In the case of the temporary shafts, frames or settings of 10-inch × 10-inch or 12-inch × 12-inch timbers are placed at vertical distances of from 2 to 6 feet according to the ground, and 1¼-inch to 3-inch poling boards placed behind them between the settings, the distances between the settings being preserved by means of props of round timber 8 or 16 to a setting.

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[1] *Proc. Inst. C.E.*, lxxxvi. 45.

[2] *Ibid.*, xliii. 197.

[3] *Ibid.*, cxvi. 121.

A detailed description of the timbering of the shafts of the Ampthill tunnel is given in the *Proc. Inst. C.E.*, cxx. 335. These were 10 feet 10 inches in diameter with 14 inches of brickwork all round, and this was propped up from below instead of being hung from above as described. The 14-inch thickness was increased to 18 inches on the kerbs, which were 30 feet apart, and to 2 feet 3 inches in certain places. The ground was excavated to the exact outside diameter of the brickwork, and temporary circular frames supporting 1½-inch poling boards were placed 3 feet apart vertically, all vacuities being filled in as the brickwork was built.

The sinking is generally done by means of a winding engine, but jack-rolls may be used until the engine is in working order.

It is sometimes necessary to line the shafts to keep out the water. The lining may be of cast-iron plates 1 inch thick, for 9-foot diameter, with 3½-inch flanges, and in 5-foot lengths. It is advisable to leave a hole in the plates and attach a pipe to it, to let off the surplus pressure of air and water, by leading it to the top of the shaft.

When the shafts are some distance apart a bottom heading is occasionally driven. This insures accuracy in the setting out, and facilitates progress, since, by means of "break-ups" between the shafts, more faces can be worked. It might be thought that because a top heading is necessary for getting in the crown bars in any case, a saving might be effected by making it continuous, but, for practical reasons, this is not so. The heading should be 8 feet 6 inches wide and 7 feet 6 inches high between the trees, to allow the passage of waggons. A bottom heading should never be driven in the London clay, as this ought not to be exposed to the air for a longer time than is absolutely necessary. It is better for the progress to be less, and accuracy in setting out can quite well be obtained without it.

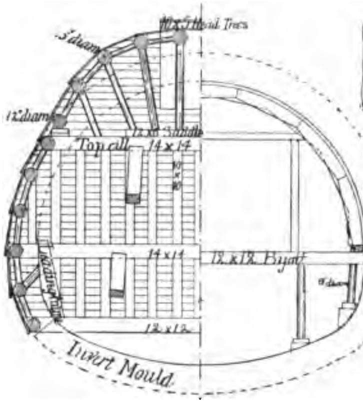

FIG. 52.

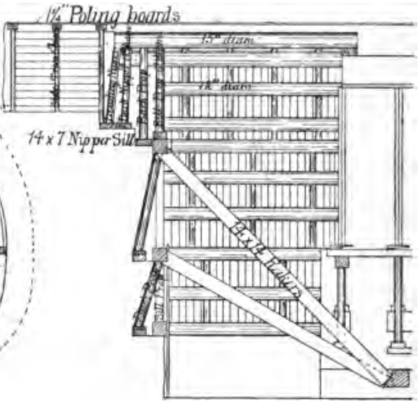

FIG. 53.

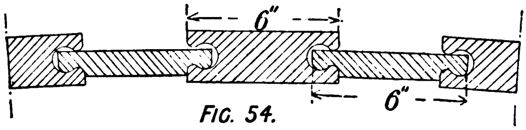

FIG. 54.

A longitudinal section illustrating the common mode of timbering is given in Fig. 53, and a cross-section in Fig. 52. The top heading, 7 feet square, is first driven to get in the crown bars. The lengths are known as shaft, side, leading, and junction lengths. They are usually about 12 feet long, but sometimes in bad ground or under buildings only 9 or even 6 feet. The bars, which are generally of larch, vary in diameter from 16 to 10 inches, according to their position and the nature of the ground; the rakers and sills may be 14 inches × 14 inches, and the props to the latter 10 to 7 inches diameter. Temporary raking props must be inserted to carry each sill until the one under it is in; 4-inch diameter props should be placed between the bars, and 1¼-inch poling boards used throughout. In some cases allowance must be made for the ground swelling and forcing the timber in. As much as 6 inches is sometimes required for this at the sides and 18 inches at the crown, the leading ends of the crown bars being raised above the horizontal line to get this. Experience has shown that the weight on the top where the covering is small is much greater than when the tunnel is considerably below the surface, for in this case the ground to some extent supports itself.

Invert moulds and side-wall profiles or leading frames must be set to guide the bricklayers, and the courses must be marked on all of these as well as on the centres before they are sent below to make sure of their meeting properly in line, and the marks should agree perfectly whichever way the centres are put.

The side bars are taken out as the brickwork proceeds, and brickwork is built between the six crown bars to support the poling boards, so that these bars can be drawn forward, this being done by means of jacks if pinch-bars will not move them. The spaces left by the bars must be filled in with concrete or other solid material.

In tunnelling under buildings, the crown bars must be left in, and the space between them filled in with solid brickwork or concrete.

The completion of a length in 10 days or 20 shifts would indicate good progress, one gang having two faces to work at alternately.

In constructing the King's Cross tunnel under some heavy warehouses, it was necessary to build brick piers to below the level of the invert to carry the columns temporarily, and to afterwards cut away the brickwork and complete the arch by means of a mass of concrete, the upper portion, which was put in before the tunnel reached it, being temporarily carried by the brick piers.

Owing to the small space between the crown of this tunnel and the surface, the ordinary bars were displaced by steel needles, as shown in Fig. 54.[1] These were 10 feet long, and were forced forward by jacks 2 feet at a time, and gave a nett length of 6 feet 3 inches for the bricklayers to work on, as 9 inches of their length rested on the finished brickwork and 3 feet on timbers in front.

The system introduced by Mr. Greathead of constructing tunnels of cast iron by means of a shield is illustrated in Figs. 55

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[1] *The Engineer*, August 5, 1892.

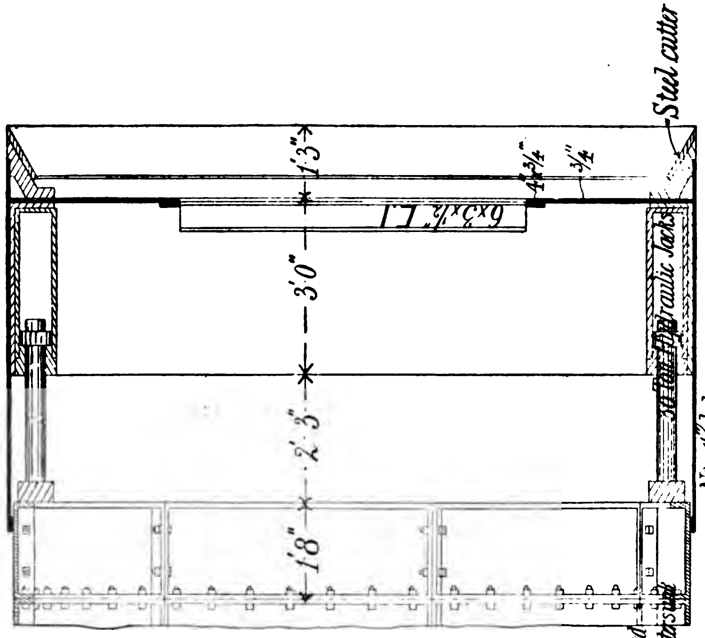

Steel cutter
1'3"
4¾"
¾"
6x3½x½" L I
3'0"
3 Pair Hydraulic Jacks
2'3"
No 2 ¼ plates
1'8"
½" Steel skin formed of 2-¼" plates. Rivets countersunk

FIG. 56.

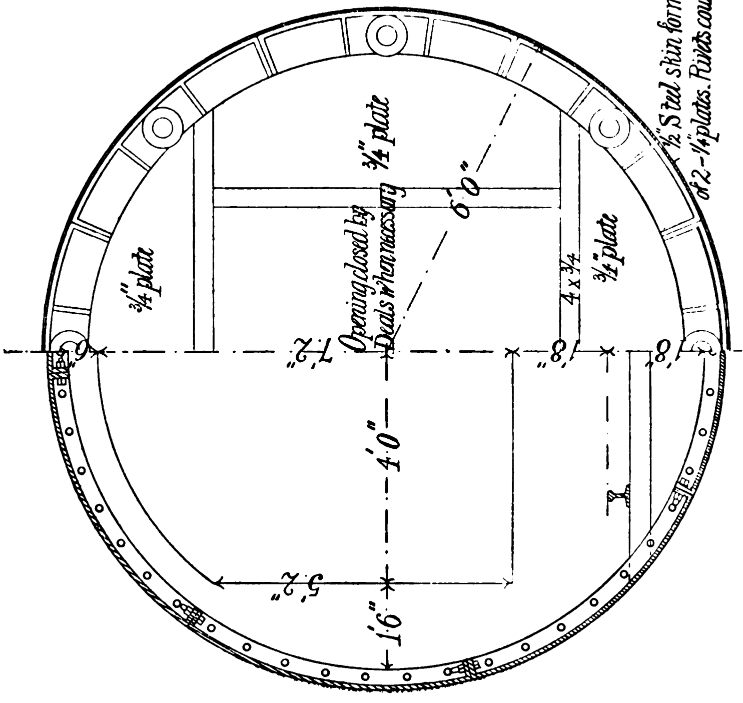

¾" plate
¾" plate
¾" plate
Opening closed by Deals when necessary
4 x ¾
6'0"
7'2"
1'8"
1'8"
4'0"
5'2"
1'6"

FIG. 55.

and 56. By making the entrances to the carriages at the ends, it has been possible to reduce the diameter from the 16 feet required by the ordinary rolling stock to 11 feet 6 inches, and even less, since doors opening outwards are not required. The left-hand side of Fig. 55 shows the completed tunnel with the carriage inside. The lining is made up of seven segments and a 9-inch key, the length of the ring being 1 foot 8 inches longitudinally. The metal is $\frac{7}{8}$ inch thick and the flanges are 4 inches deep, so that the external diameter is 11 feet 8 inches. The flanges are stiffened by gussets 9 inches apart, and bolted with 1-inch bolts 9 inches apart each way. The plates are not machined, the joints being made with soft-wood packings, and run with cement in dry ground and with iron filings and salammoniac in the proportion of 1 lb. of the latter to 400 lbs. of the former in wet strata, before the air-pressure that must be used in this case is taken off.

The mode of construction is comparatively simple in dry ground. The shield is forced forward by hydraulic jacks, which thrust against the completed tunnel until a clear length of 1 foot 8 inches is gained, and then the segments, which weigh about 5 cwt. each, are put together by hand, and the joints made, the space left by the skin of the shield behind the last ring being then filled up with lias-lime grout. This is mixed in a cylinder, and the air-tight cover then fastened down, and air at a high pressure acting on its surface forces it through a valve at the bottom through a flexible hose-pipe, which is screwed into holes which are left in the plates, the grout in the mean time being kept in a state of agitation by paddles worked by a shaft through a stuffing-box.

The hose is first attached to the bottom holes, and, when the grout begins to flow out of those just above, it is attached to these, the lower holes being stopped up by screw plugs, and so on till the top is reached, and then the full air-pressure causes the grout to flow into every cavity. The grout is prevented from flowing out between the last ring and the skin of the shield by the wooden ring, which distributes the thrust of the jacks used in forcing the shield forward. If the lime is fresh, and three parts of lime are used to one of sand with not too much water, the grout will set in 20 minutes, and become as hard as the clay it replaces. If too much water is used and the lime is not fresh, it will shrink in setting instead of swelling, and so leave a cavity. The central part of the excavation is done by hand, a square heading being driven; but the shield, which has a cutting edge, in being forced forward removes the outer portion. The cutting edge is adjustable, so that a slightly wider area can be excavated in going round a curve.

In passing through water-bearing strata great difficulties are often encountered, especially when open ballast with only a small amount of cover is met with. The work must be carried out under a pressure of air which is high enough to balance the water at the bottom, so that the air-pressure must be higher at the top than the water-pressure, and a greater or less amount of air will escape, according to the nature of the ground; and sometimes, with but little warning, a blow will take place, resulting from which the air-pressure will suddenly fall, and the water rush in and fill the tunnel in a few seconds.

If water may be met with any time, an air-lock should be built in the finished portion of the tunnel. Besides the lock for passing men and materials, pipes should be provided for passing (1) the compressed air and (2) the high-pressure compressed air for the grouting apparatus, (3) water for the hydraulic rams and (4) water for general purposes, (5) telephone and electric lighting wires, and (6) long rails—this last being formed as a lock. The large lock should have two sets of valves, one for lowering the pressure suddenly for passing materials, and one for doing this more slowly for passing men. In the top of the tunnel iron curtains should be fixed to retain sufficient air in case of a sudden rush of water, so that the men may be able to keep their heads above water, as in a diving-bell.

On the City and South London Railway poling boards were put ahead of the shield, a short length round the circumference being poled at a time, and grout was injected behind them to reduce the loss of air. On the City and Waterloo Railway a shield with the top in advance of the bottom was employed. A pot-hole, about 1 foot diameter and 2 feet long, extending to 2 inches outside the cutting edge, was excavated at the top and filled with clay, and then another each side, and so on, until the shield for the greater part of its circumference had a clay ring to cut its way through. The face of the excavation must be timbered and grouted, the timbers being temporarily strutted against the shield, rakers through the opening being fixed when the shield is moved forward. Seven or eight presses, each capable of exerting a force of 30 tons, are required to move the shield for an 11-feet tunnel easily round sharp curves, but generally only one-fourth of this pressure is required, the skin friction being about 4 or 5 cwt. per square foot.

The shield for the Blackwall tunnel was divided into twelve compartments, which were closed by shutters which slid back as the shield was forced forward, and were moved forward again by getting out the ballast through small doors. To prevent a blow where there was only a slight cover, and that of ballast, clay was tipped over the top of the tunnel in the river, and afterwards removed.

Full details of the City and South London Railway, the Waterloo and City Railways, and the Blackwall tunnel may be found in the *Proc. Inst. C.E.*, vols. cxxiii., cxxxix., and cxxx.; of the Metropolitan and Mersey Railways in vols. lxxxi. and lxxxvi.; and of other tunnels in vols. xliii., xlix., cxiv., cxvi., and cxx.

# CHAPTER X.

## *STATIONS.*

**Low platforms—Shelters—Cattle-pens—Small and large station yards—Signalling—Sidings—Loading docks for horses, carriages, cattle, and stone—Goods sheds—Roadways—Shunting sidings—Buffer-stops—Station buildings—Platelayers' cottages—Engine sheds, ashpits, and coal-stages.**

It has been already stated that, although no station buildings or platforms are actually required, some sort of accommodation should nearly always be provided at stopping-places. Expensive overhanging platforms 3 feet high are not necessary, but if the ordinary rolling stock is to be used, the roadway adjoining the line should be raised 6 inches or a foot, and a concrete or stone kerb placed 4 feet 9 inches from the centre of the line, so as to clear the sleepers, as in Fig. 57, or else a plank may be spiked to the sleepers, as in Fig. 58; but as this would only be 4 feet 2 inches from the centre, it must not be more than 9 or 10 inches above the rails.

Signals are only required at passing-places, but, when no man is to be kept at a station, the points should be locked by a key attached to the train staff. No booking-office is necessary, as the guard can issue tickets in the shelter, or, in the case of corridor carriages, in the train itself.

The simplest kind of station that can be put is illustrated in Fig. 59, in which a platform 100 feet long, and a siding, capable of holding a dozen trucks, with a shelter 12 feet × 6 feet and a lock-up about the same size, is all the accommodation provided. The points and catch-points can be worked by a single lever, and the lock-up is so placed that it can be reached from the siding as well as from the platform. It is useful for a platelayer to live on the spot, as his wife can open the lock-up and shelter and attend to the gates, and perhaps issue tickets, receive parcels, etc. The cottage shown in Fig. 71 is designed with this idea, the front room

FIG. 59.

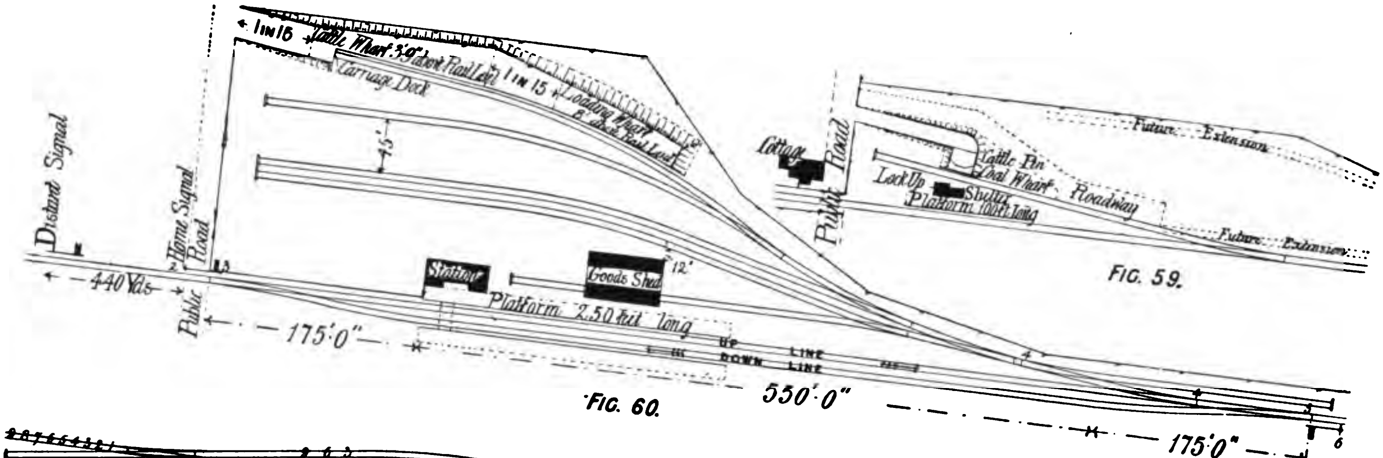


FIG. 60.

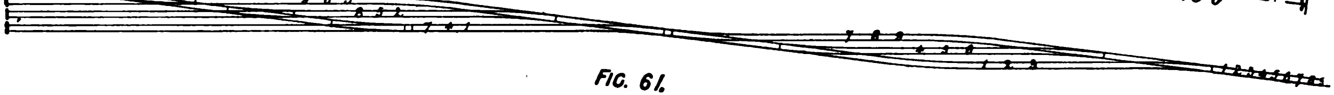


FIG. 61.

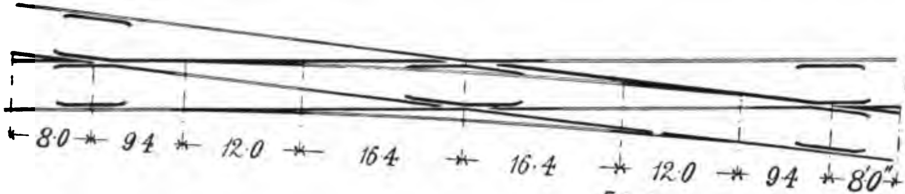


FIG. 62.

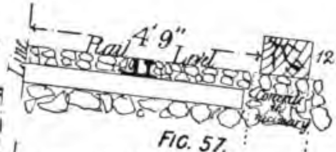


FIG. 57.

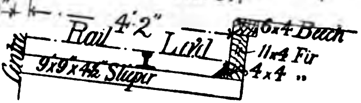


FIG. 58.

being intended to be utilized for the purpose, as in a country post-office. It may be necessary to add a cattle-pen, as in Figs. 15 or 16, but an ordinary wharf wall is more generally useful. The approach to a cattle-pen should not be fenced off from the public road, or it will have to be pitched. The cattle-pen itself must be pitched if it is fenced in all round as in Figs. 15 and 16, but cattle can be loaded from an open wharf on which temporary guard-rails can be put leading to the cattle-waggons, and, if this is open to the road, no pitching at all is required. Water-troughs must, of course, always be provided, and, to save shunting, room should be left in the siding for several cattle-waggons beyond the pen. On one side of the siding there should be a metalled roadway about 20 feet wide, and a width of 30 or 40 feet should be formed for coal and other wharves, and a roadway made beyond, wherever these can be got in. The roadways should be constructed in the ordinary way, but for the wharves a thickness of 6 inches of soft stone or chalk is quite sufficient unless the ground below is very soft.

In Fig. 60 a sketch is given of a passing-place with the points far enough (300 yards) apart to enable trains of twenty-five trucks to clear each other, and here there are several sidings and a goods shed, which is placed, like the cattle-pen in the last example, so that several trucks can be loaded and passed forward without fouling the buffer-stops or points. At such a station a man must necessarily be kept, but at a simple passing-place no one is required, as the guard can set the points and signals before leaving, and, these being properly locked, no accident can happen. The points can be worked from ground frames at each end with a pair of locking wires between or from a single apparatus on the platform. Only one signal is wanted at each end, unless it cannot be seen from a quarter of a mile off, and then a distant signal must be put at this distance, or further in the case of a steep gradient falling towards the station.

Assuming that the up signal is not visible at a quarter of a mile off, and that the down is, the apparatus would contain the following levers:—

(1) Up distant signal.
(2) „ home „
(3) „ facing-points.
(4) Siding-points and catch-points.
(5) Down facing-points.
(6) „ home signal.

(1) and (2) must be so locked that they cannot be lowered unless the points (3), (4), and (5) are set right for an incoming up train

and (6) is at danger, and so for a down train. Facing-point locks and parallel bars can be dispensed with, but it must be arranged that the signals cannot be lowered unless the points are quite shut. The numbering being always from left to right is on the assumption that the ground frame is on the down side, but it would be more conveniently placed on the up side by the station. It is generally sufficient to place the signal arms 15 feet above rail-level, and if this is 2 feet above the surface, the posts, to give the necessary 4 feet in the ground, must be 21 feet long. They should taper from 11 inches × 11 inches to 7 inches × 7 inches, and be fixed in the ground with cross-pieces and stays. The signals may be worked by 7-strand light signal galvanized wire, running on side or angle pulleys 30 feet apart, attached to 3-inch × 2½-inch posts 4 feet 6 inches in the ground, and the points by 1¼-inch outside diameter gas-piping jointed by 1-inch × ⅛-inch keys and plugs, running on 3-inch diameter plain rollers placed 7 feet apart, and on 7-inch × 2½-inch boards 16 inches long, with plain vertical compensators, and 9-inch × 10-inch cranks.

The sidings should be put in pairs with 45-foot roadways between, and be all under 400 feet in length. If they are made much longer than this a good deal of time is wasted in shunting. Plenty of land should be bought, and all laid out with a view to future extension, for it is impossible always to foresee to what extent the traffic will grow, and it is well always to keep down the first cost as much as possible.

The station shown in Fig. 70 could be somewhat cheapened to meet this case, for it can be entered from the end, and the passage past the booking-office saved, so that the entrance to the platform is the only one that need be provided. For the protection of horses and carriages the line from the road to the station should be fenced. The goods-shed dock should be at the end, so that carts backing in may not obstruct the way past it. A loading dock is here provided. An incline of 1 in 15 brings the roadway to 4 feet 3 inches above the rails, the proper height for a carriage dock, and a slight fall reduces this height to 3 feet 9 inches for the wharf for loading horses and cattle. A further rise at 1 in 15 increases the height of the roadway to 8 feet, which elevation is sufficient for carts to tip ballast and similar things straight into the trucks.

Details of a carriage dock are given in Figs. 63 and 64. The height of this above rail-level is made 4 feet 3 inches, so that the wheel-plates may clear the buffers and incline a little towards the truck, the floor of which is 3 inches lower. Fig. 63 is a cross-section and Fig. 64 an elevation of the carriage dock. A section of the standard wharf for loading cattle and goods is also given in Fig. 64, and in Fig. 65 the higher wall is illustrated. In both these cases the coping should be 4 feet 9 inches from the centre line of the siding. Except for carriage docks and the special traffic provided for in Fig. 65, all wharf walls should be 3 feet 9 inches above rail-level, whether they are for horses, cattle, or goods, so that the flaps of the trucks may lie level. Fig. 64 gives the end of a cattle wharf where it is rising from the 3 feet 9 inches to 4 feet 3 inches above rail-level for the carriage dock. Unless there is a special traffic a crane is not wanted, as a travelling crane can be brought from the depôt to unload anything that is particularly heavy. Coal, bricks, and such-like materials, that are forwarded in full truck-loads, are unloaded in the open, but the more valuable consignments must be treated in the shed, and sometimes it is absolutely necessary to unload under cover. In some cases a truck may contain consignments for several stations.

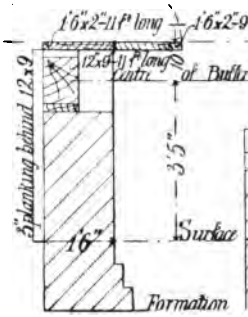


FIG. 63.

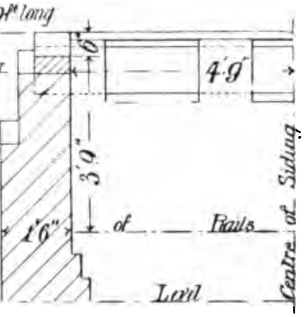


FIG. 64.

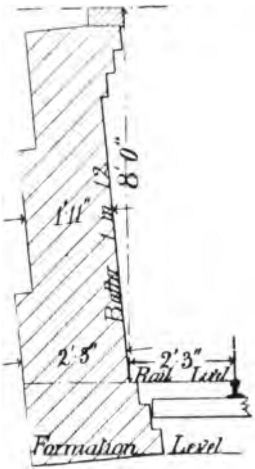


FIG. 65.

These are called " brake " goods, and it is for them that the small lock-ups on the platforms illustrated in Figs. 59 and 66 are provided. The most economical shed for warehousing goods or grain is shown in Fig. 67, but for dealing with a large traffic that does not require a lengthy storage, Fig. 68 is more suitable. In this a small office for the use of the goods clerks is required, since a special staff must be employed where there is much goods traffic.

An allowance for a load of 1 cwt. per square foot is sufficient for the floor of the office, but for the shed itself 3 cwt. must be provided for. One-inch boarding on 7-inch × 2-inch joists, a foot apart, will be safe for the office, if the span of the joists is not over 10 feet; for the shed 2½-inch planking on 9-inch × 3-inch joists, 2 feet apart, is sufficient, if the span is not over 8 feet; provision must be made for wear, the boards being tongued with hoop-iron near the bottom, and the nosing should be made of beech, elm, or pitch-pine to withstand the rough usage it is likely to get. The wall-plates should be 4½ inches × 3 inches. If 1-inch slate boarding is used, the purlines should not be more than 4 feet apart; and if these are 9 inches × 3 inches, the span should not exceed 8 feet. The pitch of a slated roof may be 2 to 1, but nearly 1 to 1 is necessary for tiles.

The width, 45 feet between the sidings, in Fig. 60 is the least that should be given, for it is necessary for carts to pass to and fro while others are loading on each side, the actual length of a van, without the horses and pole, being 12 feet 6 inches, so that the standing vans alone take up 15 feet from the rail on each side, leaving only 15 feet for the horses and carts that are passing to and fro, and, besides this, stacking spaces are required.

Shunting sidings should, if possible, turn off the distributing road at an angle of 1 in 8, but in case of need this angle may be made 1 in 6, but no sharper, for at 1 in 6 there is only just room to get in the points clear of the crossing. On the other hand, nothing easier than 1 in 8 should be introduced for through roads, especially if these are curved, trucks being so liable to get off the line at very long elbows.

A good deal of saving in labour and engine-power can be effected by shunting by gravitation, as in Fig. 61, which illustrates a double gridiron, by which nine trucks can be arranged in any desired order. For any ordinary light railway five sidings would be sufficient in each grid, as these would arrange twenty-five trucks in any order. The dead ends in Fig. 61 are not necessary for the

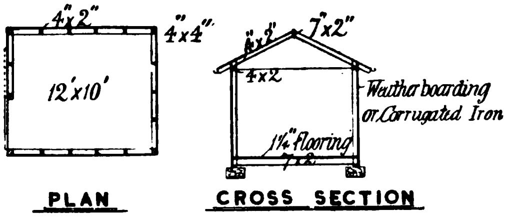


FIG. 66.

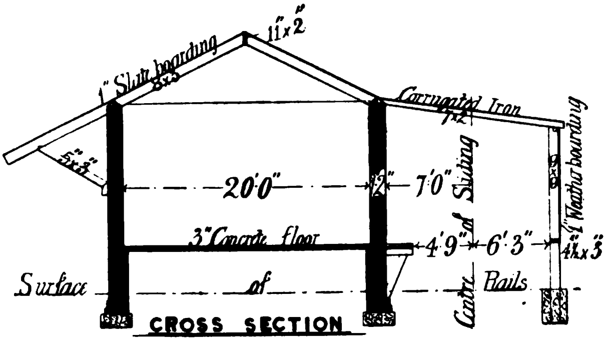


FIG. 67.

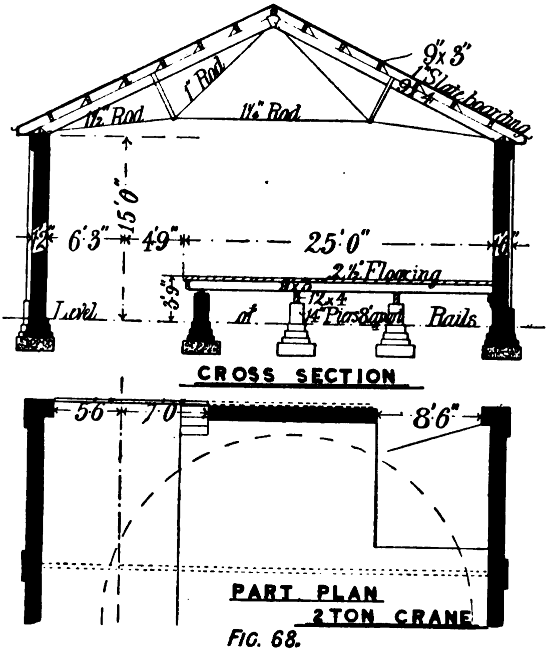
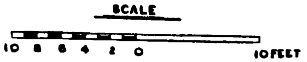


FIG. 68.



arranging of the nine trucks, but would come in if more than nine trucks were being arranged. An enlarged view of one of the compounds is given in Fig. 62. To avoid short rails the elbows, or diamonds, as they are sometimes called, are here lengthened to fit against the stock-rails of the switches, which are a foot longer at each end than the tongues. The crossing-rails are continued to 8 feet 4 inches from their centres, also to make them fit against the stock-rails. Full detailed drawings of all points, crossings, and elbows must be furnished to the makers, and these must be prepared in such a manner as to agree with the lengths of the rails supplied, to save cutting as much as possible. In all station yards a gradient of, say, 1 in 100 is useful for moving trucks without a horse and without waiting for an engine.

The distance between adjacent lines of rails must be 6 feet, as on a main line, so that with rails 1¾ inches in width the distance apart, centre to centre, is 4 feet 8½ inches + 6 feet + 3½ inches, or 11 feet instead of the 11 feet 1½ inches which is required when the rails are 2½ inches wide.

As with the ordinary railway, no structure from 2 feet 6 inches to 11 feet above rail-level must be within 7 feet of the centre of any passenger line, or 5 feet 6 inches in the case of any goods line, unless a special rolling stock is used, and nothing on a platform must be within 6 feet of the coping edge, or, say, 11 feet from the centre of the line.

All sidings running on to or across main lines must have catch-points as near the 6-feet clearing-point as possible.

The cheapest and best buffer-stop is a mound of earth, which must be kept up to make a *buffer*-stop and not a *wheel*-stop, which latter is liable to break the axle-boxes. If room does not admit of this, a timber-stop may be constructed, as in Fig. 72, or one formed of rails, as in Fig. 73.

A crane to lift 30 or 40 cwt. is enough for a goods shed, but sometimes one to lift 5 to 20 tons is required in the yard.

At some stations weighbridges for carts or trucks are required, but at most places small platform scales are sufficient.

The station buildings shown in Fig. 70 are designed for a small country town. The booking-office, cloak-room, and parcels-office, for which one room is here provided, should be close together, and near and communicating with the station-master's office in all cases, so that one man can attend to the whole business in case

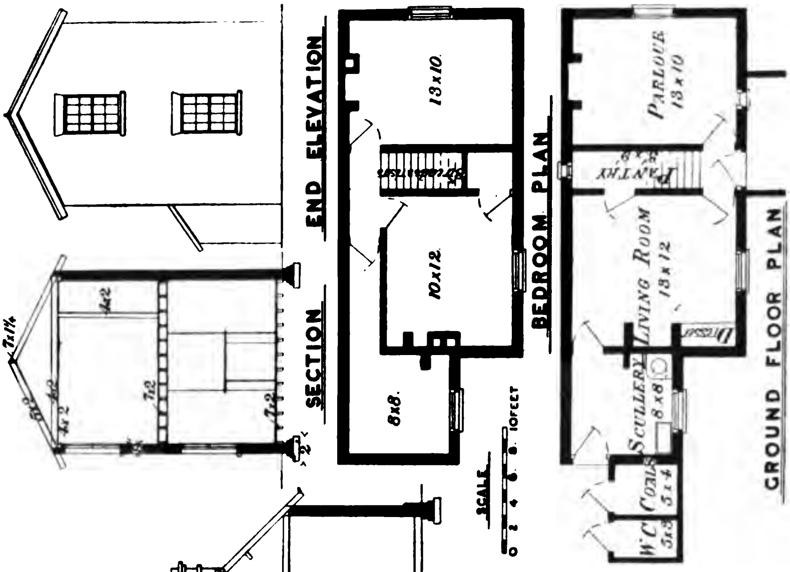


FIG. 71.

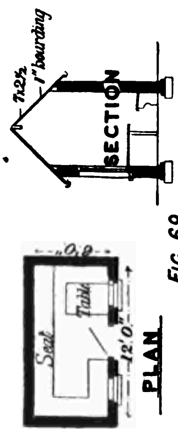


FIG. 69.

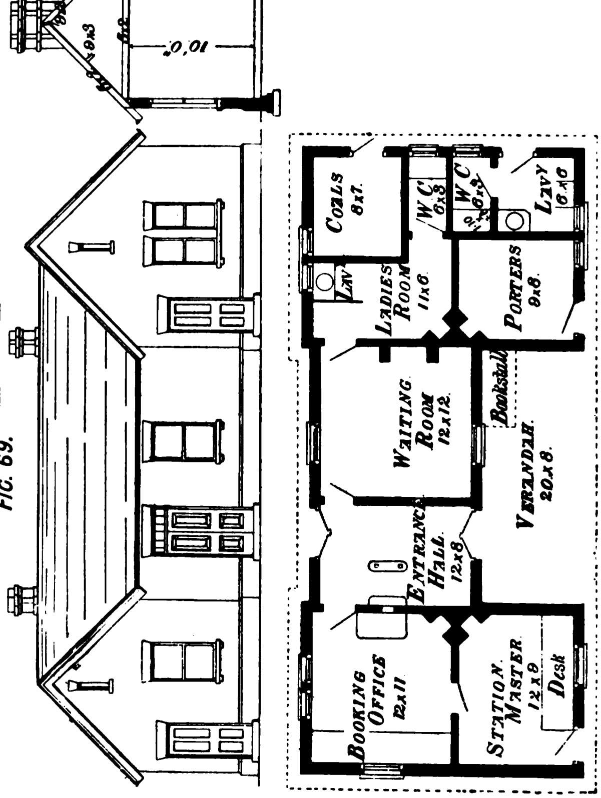


FIG. 70.

of need; while the lamp and porters' room and the gentlemen's lavatories can be at the other end of the building.

The ticket-windows should be 12 inches wide and 18 inches high on a shelf 3 feet 6 inches above the floor. Outside, this shelf should be about 9 inches wide and 4 feet long, so that a passenger can rest his bag on it while booking; and there should be another shelf the same width and height 2 feet away, carried by two 4-inch × 4-inch posts to act as a barrier. Inside, the shelf should be hinged so that it can form the door to the opening, and not cause an obstruction on the desk, which should be 6 or 9 inches lower. By the ticket-window a space should be reserved for a ticket-case 3 feet wide, with opening wings of 18 inches each side, so that this requires a wall-space of 6 feet in all. In Fig. 70 it would be put over the chimney-piece. Book-racks and drawers should be placed wherever there is room, leg-space being reserved for the clerks, so that they may sit in comfort; plenty of 11-inch shelves should also be put, and a trap left in the roof so that papers can be stored there, the ceiling-joists being roughly boarded over for this purpose. In the cloak-room and parcels-office shelves 3 feet wide and 3 feet apart should be provided for luggage.

FIG. 72.

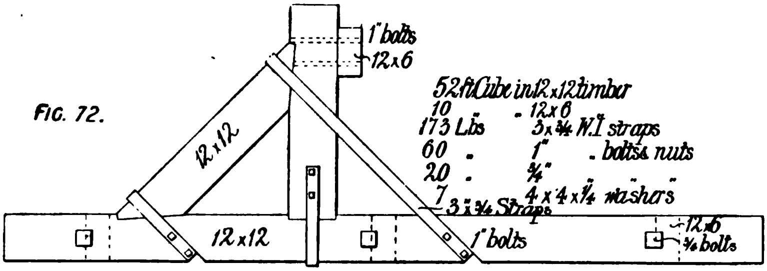
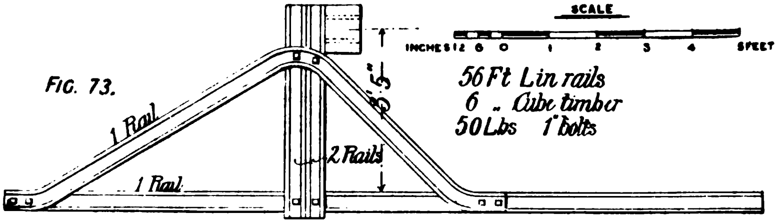


FIG. 73.



A space at the end of the building next to the booking and station-master's office should be reserved for extension in case the traffic should grow.

All walls, both in the offices and waiting-rooms, should have splines, about 2½ inches × ¾ inch, plugged to the walls all round, on which files or advertisements can be hung. No cornices are required, but picture-rails should be put.

The doors in the entrance hall should be double, and 4 feet 6 inches wide to admit the luggage barrows. To enable these to clear the booking-office barrier and to give room for labelling, this hall or passage should be 8 feet wide. It often forms part of the general waiting-room, but this arrangement makes the latter draughty. The ladies' waiting-room, which is really only a lobby to the w.c., should contain a looking-glass and washhand basin. It is better to put all the cisterns to the w.c.'s, etc., in the roof, as they are there more easily attended to and are not so unsightly, and besides, being higher up, the flush is better, and they can be more easily protected from frost. All w.c.'s should be against outside walls, and have open louvres above the windows for ventilation, for light and air are of the first importance. The pedestal closets, which are unenclosed, are the best to use, and, even for the gentlemen's lavatory, it is better to put mahogany seats. The ladies' w.c. should be 6 feet × 3 feet, but the gentlemen's may be a little smaller, say, 5 feet × 2 feet 9 inches. Even if the water-supply is constant, it is better to have a 100 or 200-gallon tank in the roof to provide against accident. This tank should be high enough to feed the w.c. cisterns and the syphon to the urinals, and should be connected with the main by an inch galvanized pipe, on which there should be stop and draw-off taps for use in frosty weather. Water-cocks should be fixed in the ladies' waiting-room, gentlemen's lavatory, and porters' room, and there should be a fire hydrant on the main. The urinals should have 1-inch slate divisions with rounded nosings, placed 2 feet apart, 5 feet 6 inches high, and 1 foot 6 inches deep, with a ¾-inch slate back, blue brick channel, and concrete floor, the flushing being done by a syphon leading to perforated pipes all round. Like the w.c.'s, the urinal should have plenty of permanent ventilators and lights.

The porters' room should be fitted with a seat all round with lockers under it, and a small cooking-stove should be provided. The coal cellar should be large enough to hold rather more than a truck of coal, and to save space the door should open outward. The walls and ceilings of all the offices and waiting-rooms should be plastered, but the coals, lamp, and porters' room only require limewhiting. Wherever luggage is handled the walls ought to be boarded to a height of 3 feet. Sometimes the ceilings are boarded, but this is not clean, and does not look well.

Refreshment-rooms are sometimes required at junctions and terminal stations. They should have counters 2 feet 6 inches wide and 3 feet 6 inches high, with a space of 4 feet 6 inches behind, a foot of this being taken up by shelves, which should be placed in tiers 18 inches apart. In front of the counter there should be a space of at least 5 feet, or more if dining-tables are to be accommodated. These are usually 3 feet 6 inches square, and to enable people to sit all round, a space of 7 feet square would be taken up by each, or more if space has to be provided for people to pass between. The cellar should be 6 or 9 feet wide, according as room is required for one or two rows of barrels, the extra width being required for getting them in and out. A small kitchen with cooking-range and pantry is also necessary.

The lamp-room should be detached, if possible, to reduce the risk of fire, and, in case the coal-cellar should at a future time be wanted for some other purpose, it is as well to put a window in it to save cutting afterwards.

The small shelter illustrated in Fig. 69 is for a wayside station where no man is kept. It should have a seat all round and a small table on which the guard can issue tickets, and should be capable of being locked up at night.

A plan of a platelayer's cottage is given in Fig. 71, and an estimate for the same in Appendix L. From this it will be seen that it is almost impossible to build a cottage to yield a fair return for the money spent, but a considerable saving can be effected by building in pairs or rows. The accommodation shown is about the minimum of what should be provided. The front room should have a small wicket for inquiries, issuing tickets, receiving parcels, etc., and the instruments should be put in it, if there is a telegraph.

The inside walls of the outbuildings, scullery, and pantry may be limewashed, but all other walls ought to be plastered. The floors of the scullery and outbuildings should be of cement, but all other floors should be of wood. The doors to the outbuildings and cupboards may be ledged, all the others being panelled. Full details as to the necessary finish and fittings can be obtained from the quantities in the estimate. No attempt has been made to make this cottage ornamental, for creepers can be planted and in a short time the ugliness will have gone.

At some point on the line accommodation must be provided for the locomotives and rolling stock. The running-sheds should be large enough to house all the engines, and sufficient room must be given either at the end or side for the sand-drying furnace, tools, and fitter's bench and foreman's office. Eight or ten feet should be given between the lines, to give room for lifting the engines and fitting new brasses, wheels, springs, etc. An ashpit, as shown in Fig. 74, should run the entire length of the shed, and others should be provided outside. Shear-legs and tackle for lifting an engine, one end at a time, off its wheels are necessary; and if there are several engines, a wheel-lathe, drilling and other machines, and a smith's shop will be wanted. For the carriages and waggons there should be separate sheds, and something is required for the platelayers to repair points and levers in case of an accident.

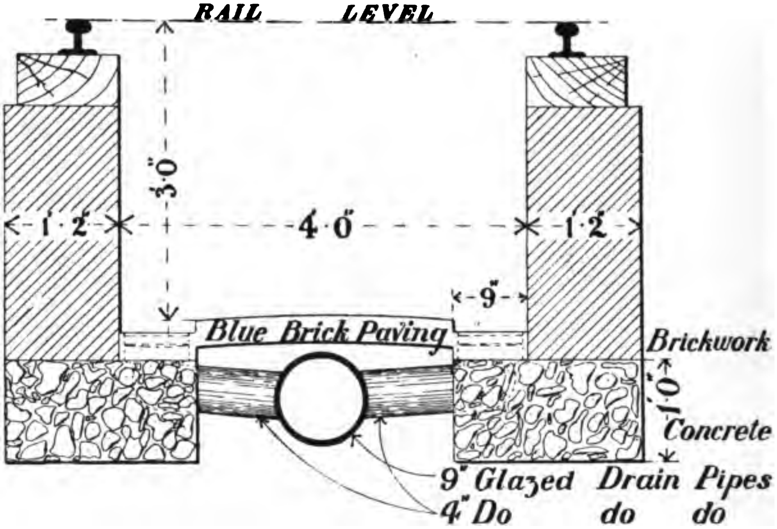


FIG. 74.

Coal-stages are either made 3 feet 9 inches or else 10 feet above rail-level. In the first case they should be made the same distance from the centre of the line as the other platform, viz. 4 feet 9 inches; but in the latter they may overhang a little. In both cases small cranes and weighing-machines should be provided for coaling the engines; and in the latter there should be a siding, 6 feet 3 inches above the locomotive siding, for unloading the coal from out of the trucks. Water-cranes and tanks must be provided at the coal-stages and other points on the line.

# CHAPTER XI.

## *DRAINAGE AND WATER-SUPPLY.*

**Rainfall—Floods—Discharge of conduits and pipes—Water—Filtering—Reservoirs—Mains and service-pipes—Sewerage—Flushing tanks—House drains and main sewers—Manholes—Ventilation—Sewage disposal—Points of importance in drainage.**

THROUGHOUT the line, during construction, and at stations and locomotive depôts after it is opened for traffic, the provision of a good supply of water is absolutely necessary. It generally happens that the water is present where it is not required, and hence it is the business of the engineer to guide it into the proper channels, and to provide for the rapid removal of any excess, so that the subjects of the present chapter should naturally be considered together.

**Rainfall.**—The sun heating the air near the equator causes it to rise laden with moisture and to move towards the poles in an upper current, its place being taken by the cold air moving in the opposite direction. The south-west wind in this country is therefore mild and saturated with moisture, and the north-east wind cold and dry. This action is, however, complicated by many local conditions which it is unnecessary to enter into here. The moisture of the mild south-west wind, chilled by contact with high ground, becomes condensed, and drops in the form of rain; the wind then passing on to ground of a less altitude, has not much moisture left, and so the fall on such low-lying ground is less. This accounts for the fact that the rainfall on the west side of Great Britain, where the ground is for the most part of considerable elevation, is from double to ten times greater than on the east coast, where it averages less than 20 inches in the year.

Not only is the rainfall very different in different places which are near together, but also it varies in different years to a very great extent, and in some countries more than others; thus the average annual fall at Greenwich for the last fifty consecutive years was about 25 inches, but taking five consecutive years, it varied from 20 to 30 inches.

In parts of India, where the average fall was 30, the maximum and minimum were 70 and 15 respectively; and in Australia, where the average was 25, the maximum and minimum were 40 and 12.

In England 1½ inches have been known to fall in an hour, 2 inches in two hours, and 5 inches in a day; while in India nearly 5 inches have been known to fall in an hour, and 24 inches in a day.

On the assumption that there is no loss by evaporation or absorption, a fall of 1 inch of rain in 24 hours would give a flood of 4 cubic feet per second per 100 acres, but at Manchester and Glasgow floods of from four to six times this have been recorded. At Manchester some 70 per cent. of the fall flows off the land, but in chalky and sandy districts it is nearly all absorbed; and the river Thames only delivers 4 inches out of a total of 24, the rest being lost by percolation or evaporation.

The evaporation from water in Europe averages 0·07 inch per day, and from the land 0·28 per day; while in India it is 50 per cent. more than this.

**Flow of Water.**—From 3 to 10 inches per mile is the best inclination for a conduit with earth slopes. On the Ganges Canal inclinations of 16 and 13 inches per mile produced currents of nearly 5 and 4 feet per second respectively, and the bottom and slopes were in consequence damaged, for a velocity of 3 feet per second will move gravel, and even 1 foot per second will move sand. With 2 to 1 slopes almost any soil will stand a current of 2 feet per second, and thus the 6 inches per mile fall that was adopted on the Eastern Canal of France and the New River was found to be quite satisfactory.

The discharge of an open channel or sewer-pipe is given by the following formulæ:—

$$V = 94\sqrt{sa}, \text{ and } Q = 94A\sqrt{sa}$$

where V is the mean velocity in feet per second, the surface velocity being 25 per cent. greater than the bottom;

$s$ is the ratio of the slope, *i.e.* the fall of the channel divided by its length;

$a$ is the hydraulic mean depth, *i.e.* the sectional area divided by the wetted perimeter;

Q is the number of cubic feet delivered per second;
A is the sectional area of the channel in square feet.

For pipes under pressure—

$$Q = 94\sqrt{\frac{h}{l}.a} \times A$$

$$= 47\sqrt{\frac{h}{l}.d} \times \tfrac{22}{7}\left(\frac{d}{2}\right)^2 = 37\sqrt{\frac{h}{l}.d^5} = \tfrac{1}{14}\sqrt{\frac{h}{l}.D^5}$$

where $h$ is the head in feet;
$l$ is the length of the pipe in feet;
$d$ is the diameter of the pipe in feet;
D is the diameter of the pipe in inches.

Applying the formula to an open channel, in which $a = 4$ feet and $V = 2$ feet per second, we get—

$$s = \frac{1}{(94)^2} = \tfrac{1}{8836}$$

and 1 in 8836 is 7 inches per mile.

For a 12-inch drain-pipe with a fall of 1 in 264, full or half full—

$$V = 94\sqrt{\tfrac{1}{264}a} \text{ and } a = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{d}{4}$$

$$\text{so } V = 94\sqrt{\frac{d}{264 \times 4}}$$

$$= 47\sqrt{\tfrac{1}{264}}$$

$$= 2{\cdot}9$$

If a supply of water is required to work a turbine or water-wheel to actuate electrical generators, and a greater velocity than 2 feet per second is necessary, the conduit can, of course, be laid to a greater inclination, provided it is pitched or lined with concrete.

**Water-supply.**—Water which contains more than 16 grains of lime in a gallon is unfit for domestic use, and dangerous to health. When it contains less than 5 grains, *i.e.* when it is of less than 5° of hardness, it is called soft. Each degree of hardness destroys 2½ ozs. of soap per 100 gallons. Hardness is of two kinds—temporary, due to bicarbonate of lime; and permanent, due to sulphate of lime. The former may be removed by boiling, and causes sediment in engine boilers.

Impure water may be improved by filtering, but filters do not always prevent the passage of the germs of disease, unless indeed some such substance as spongy iron is used. It is said that the germs of disease *can* pass through a sand filter 10,000 abreast, but as a matter of fact they do not; indeed, a sand filter not only stops the germs of disease, but many microbes that are not only harmless but actually useful for digestive purposes, experiments having shown that the filters of some of the London water companies stop 98 or 99 per cent. of the microbes.

Filtering may be done by copper screens, by settling tanks, and by sand filter-beds. The copper screens should be of sixty meshes to the inch. Filter beds are generally constructed with sloping sides; 24 inches of clean sharp sand resting on 6 inches of coarser sand, 6 inches of gravel, and 12 inches of broken stone makes an efficient filter, and this, with a head of a foot, will pass 75 gallons per square foot per diem, a rate of filtration that should not be exceeded.

An uncovered pure-water tank should be at least 15 feet deep in order to prevent vegetation.

Reservoirs should not be placed on chalk, oolitic, new red sandstone, or millstone grit, unless the bottom is concreted or puddled.

If a reservoir is constructed of concrete it should be rendered an inch thick in two coats, the first of 3 to 1 cement mortar $\frac{7}{8}$ inch thick, and the second of neat cement $\frac{1}{8}$ inch thick. Concrete, and still less brickwork, alone will not stop the water, and puddle is often difficult to deal with. A brickwork tank may sometimes, however, be made water-tight by washing it with cement grout until the bricks are thoroughly impregnated. The covering to a tank may be supported on 18-inch × 18-inch brick piers 15 feet apart, connected by cast-iron girders or brick arches 18 inches wide and 14 inches deep, and the covering may consist of 9-inch brick or concrete arches. All covered tanks should be ventilated, and have overflow and washout pipes.

Water-pipes should always be laid 2 feet 6 inches below the surface to protect them from the frost; dead ends should be avoided as much as possible, and hydrants placed at all dead ends, so that the stagnant water can be flushed out. Ball hydrants should also be fixed at all summits to prevent air accumulating. Fullway valves, with all four faces of bronze, should be so placed that any section of pipes can be cut out without stopping the rest of the supply. Small half-brick pits, a foot square with covers, should be put over all valves, larger covers being provided for the air-valves and fire hydrants, so that the stand-pipes can be introduced; pipes can be drilled and the ferrules inserted under pressure, and a stop-tap and cover should be supplied for *each* connection. Galvanized water-pipes should nearly always be used for connections, but where the pressure is very low galvanized gas-pipes tested for water may be put. Screw-down taps should always be used with a high-pressure service, to prevent sudden strains on the pipes. Lead pipes should weigh 6, 9, and 14 lbs. per lineal yard, according as they are ⅜ inch, ⅝ inch, and 1 inch internal diameter.

**Sanitation.**—In providing for the drainage of houses and station buildings the main points to be observed are—

(1) To prevent sewer gas getting into the buildings.
(2) To keep the sewers sweet and free from deposit.
(3) To avoid the contamination of streams by discharging foul matters into them.

All closets should be trapped, and discharge into a soil-pipe 4 inches in diameter, which should rise well above the roof to act as a ventilator, and the top should be well away from the windows, so that the sewer gas may not be drawn into them. At the head of the drain a flushing chamber should be provided, with an automatic syphon, if possible, and into this the bath and rain-water should be led, but not the sewage. If there are no baths, a supply of fresh water should be laid on for use in dry seasons. If this discharges weekly, the drain will be kept perfectly fresh. All drains should be laid in perfectly straight lines from inspection chamber to inspection chamber, to enable a man to see if there is any obstruction, and, for the same reason, and also to ensure a perfectly even flow and so prevent deposit, the gradient should be perfectly regular. Four-inch pipes are large enough for the connecting drains, but nothing less than 6-inch should be provided for the main outfalls. The joint should be made by a couple of turns of yarn in the collar, which latter should then be filled up with 2 to 1 cement mortar, and a fillet should be formed outside *right round* to prevent any leakage; for, if the water gets out, the ground is not only fouled, but dry deposits are made in the pipes. In bad ground the pipes should be laid in concrete, and, under buildings, this should be carried to a depth of 6 inches right over them also. A velocity of 3 feet per second is sufficient to prevent deposit, and this may be secured by the following gradients if the sewer is running half full:—

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-in. | pipes, | 1 | in | 92, | or better, | 1 | ft. in | 1 | chain or | 2 | ins. in | 11 ft. |
| 6-in. | „ | 1 | „ | 137, | „ | 1 | „ | 2 | „ | 1 | „ | 11 „ |
| 9-in. | „ | 1 | „ | 206, | „ | 1 | „ | 3 | „ | $\frac{5}{8}$ | „ | 11 „ |
| 12-in. | „ | 1 | „ | 275, | „ | 1 | „ | 4 | „ | $\frac{1}{2}$ | „ | 11 „ |
| 15-in. | „ | 1 | „ | 344, | „ | 1 | „ | 5 | „ | $\frac{3}{8}$ | „ | 11 „ |

When the flow is likely to be very small, and where good flushing arrangements cannot be made, it is better to make the falls twice or even three times as great as these.

In water-bearing strata, where it is impossible to make sure of the cement setting properly, Hassel's patent joints should be employed. The pipes for these are delivered with the composition on, the spigot being made to perfectly fit the socket, and so a perfect joint is made when it is pushed home, and this is still further secured by running in liquid cement.

Skew junctions and easy bends should be employed. Half or channel-pipes should be used in the manholes, which latter should be fitted with disc flushing-valves, to hold up the sewage or water from the flush-tank, in order to scour the next length. Manholes are generally built circular, 2 feet diameter at the top and 4 feet at the bottom, with 9-inch brickwork all round and a 12-inch foundation of concrete. The covers should be 20 inches internal diameter, and have dirt-boxes to prevent stones and the like getting into the sewers. Sometimes plates are put to stop the gas rising, but it is better to ventilate freely. Steps 12 inches apart should be built into the walls, and the bottom each side of the channel-pipe ought to be slightly sloped. Where a drain has to connect with an old sewer, the old pipe must be carefully broken and a saddle-piece fitted on, care being taken to do as little damage as possible, and to prevent the broken pieces falling into the pipe. At all changes of gradient where manholes are not required lamp-holes may be put. All that is required for these is a square junction with vertical pipes to the surface, and a small cover, so that a light may be hung down to show if the pipes are clear. They must, of course, alternate with the manholes, and, where at a change of direction, be formed with a small pit to enable the light to be properly seen.

The freest ventilation should be given to both house drains and main sewers, frequent 4-inch diameter or 5-inch × 3½-inch cast-iron pipes with well-made joints being led up adjacent buildings, to points which are well clear of windows and chimney tops. In addition, it is useful to make all lamp-posts serve also as ventilators. Sewage gas is comparatively harmless when freely diluted out-of-doors, but in a house it is dangerous. If a sewer is not freely ventilated, a rise of temperature will syphon the traps, and so the ventilators should never be more than 100 yards apart. It is important to lead away the sewage as quickly as possible, and not let it decompose in the pipes, and with a well-flushed sewer complaints as to foul smells are rare.

In a town the railway engineer has only to connect with the main sewer, and need not trouble himself further, but for country stations and cottages he has to consider the subject of the disposal of the sewage. After many years' consideration we are coming back to the old-fashioned cesspit, but we call it a "septic tank." The idea of this is to turn the sewage into a tank from which air and light are excluded, in order to encourage bacteriological life. The microbes which are always present thrive under these conditions, and break up the solid sewage into liquids and gases. The latter can be burnt by means of a Bunsen burner, and the liquid passed on to a coke breeze filter, where it is attacked by another kind of microbe, and rendered fit to run into anything. To carry out this action perfectly, the cesspit in Fig. 75 should be at least 6 feet deep, the inlet sewer-pipe turned down to 4 feet below the water-level, and the outlet to 2 feet below water-level, as the microbes work at the top and bottom; the air must not be admitted, and they should not be disturbed more than can be helped. The liquid flowing out should run along an open trench filled with small coke, to which the other microbes adhere, and should be aërated as much as possible.

W.c.'s must always be against outside walls, and the soil-pipes completely outside the house, and all bath, waste, and sink-pipes should discharge in the open a foot or two from the gulley. In addition to a window of at least 2 square feet area, the closet should have a ventilating air-brick.

Ashpits should be well away from a house, and only large enough to hold a week's accumulations. A cesspit should be at least 20 yards away from a house or stream. A cistern holding 2 or 3 gallons should be provided for flushing a closet, so that the water-main may not be in direct communication, and that waste may be prevented.

Sewer-pipes should be rather more than an inch thick for a diameter of a foot, and should be perfectly circular and free from cracks; they must ring well, and the salt glazing should render them perfectly impervious to water. The spigot ends should be laid downhill. An egg-shaped sewer 3 feet wide should be 4 feet 6 inches high, the radius of the arch being 1 foot 6 inches, and that of the invert 9 inches.

Subsoil drainage is necessary to clear off stagnant water and aërate the soil.

If the sewage is disposed of by open irrigation, an acre of land must be provided for 100 persons.

House drains can be tested by pouring oil of peppermint in hot water into them and closing all windows, but leaks must be located by the smoke test.

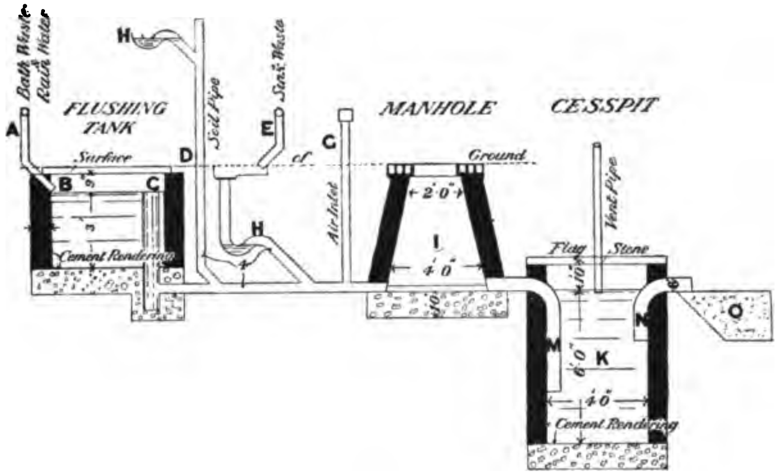


*FIG. 75.*

The diagram (Fig. 75) shows what is necessary for the drainage of a house. The rain-water pipes and bath waste here enter the flushing-tank **B** by **A**. When the water has risen to the top of the syphon **C**, it is discharged into the drain in a few seconds, and carries everything before it. The sewage enters the drain by the soil-pipe **D** and the slops by the pipe **E**, which is a foot or two away from the gulley, to cool the grease and prevent it blocking up the pipes. Air is admitted by the mica-flap inlet valve **G** to ventilate the house drains, and the warm sewer gas formed in them is allowed to escape freely from the top of the soil-pipe **D**. Any ventilation of the main drain, which does not exist here, would be by a separate pipe. The sewer gas is prevented from escaping under the scullery window or into the w.c.'s by the traps **H, H.** The house drain leads into an inspection pit or manhole, **I,** by means of which it can be cleansed by drain-rods or tested. It is led from here into the cesspit **K**, entering at **M** and going out at **N** when liquefied into the open ditch **O**, which is filled with small coke. The cesspit should be a good deal larger than the flushing-tank, so that when the latter goes off the microbes working on the sewage may not be washed away or unduly disturbed. For a small house there would hardly be enough gas produced to keep a burner always going, so a pipe is shown just going below the surface, so that the least increase in pressure will enable it to escape.

# CHAPTER XII.

## *STEEP INCLINES.*

**Cable traction—Rack-rail—Centre-grip rail—Gas and compressed air—Electricity—General principles and common systems of working—Main and sub-stations—Rail bonds—Standards—Trolley, guard, and span wires—Main feeders—Surface conductors.**

It has been stated in Chapter I. that an engine with all its weight on the driving-wheels can just ascend a gradient of 1 in 6, and that it can draw a load equal to its own weight up 1 in 14. It sometimes happens that such, and even steeper, gradients are unavoidable, and to work these a special mode of traction is necessary; indeed, it may be said that the ordinary locomotive is unsuitable for any gradient steeper than 1 in 20 on the ground of economy, and also on account of the difficulty of keeping the fire-box covered with water when running down hill with the chimney in front.

Almost any incline can be worked by means of a cable, and anything up to 1 in 4 by the use of a rack and gearing on the Abt system.[1] The centre-grip rail is not applicable to anything steeper than 1 in 12, but for 1 in 6, or perhaps it is better to say 1 in 8, any motive power, such as gas, compressed air, or electricity, that can conveniently be applied to every axle, can be made available for direct adhesion, which renders the expensive centre-rail construction unnecessary. However, it must be noted that in many cases it may be inconvenient to fit the motive power to every axle, so that in this, as in almost every engineering question, no definite hard-and-fast line can be laid down.

**Cable Traction.**—This has been used for tramways and subways where the gradients have been as heavy as 1 in 5, as in San Francisco,[2] and 1 in 9, as at Los Angelos and Lausanne,[3] but such gradients can now be worked in other ways. To assist a train up a short steep incline it is, however, invaluable, and it is the only system by which the 1 in 3·7 and 1 in 1·6 on the Stanzerk Railway[1] could be worked.

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[1] *Proc. Inst. C.E.*, lxxii. 21. [2] *Ibid.*, cxii. 123. [3] *Ibid.*, lxi. 360.

The ropes do not last much more than a year if the traffic is at all heavy, and they stretch about 1 per cent. A wire rope an inch diameter will stand a strain of 60 tons, but should not have more than 5 tons put on it.

The underground channel required for a tramway and illustrated in Fig. 76 is an expensive item, but this is not required in the case of a railway. The distance apart of the rollers should be about 50 feet on the straight, and 30 feet on sharp curves. They should be put a little on one side of the groove, so that dirt may fall clear of the cable. Each roller should be placed in a little brick pit with a hinged cover over it, and should run in well-lubricated axle-boxes and on brasses. Room is left in the underground channel in Fig. 76 for a second cable to work the return cars in the case of a single line. The little top pulleys are only required at changes of gradient to prevent the cable from rising too high. The cars are attached by means of

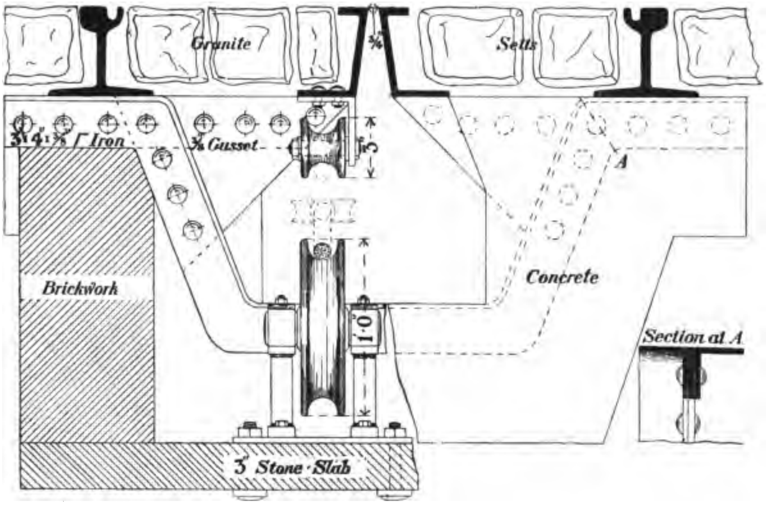

FIG. 76.

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[1] *Proc. Inst. C.E.*, cxx. 2.

pulleys, generally two on each side. These are gradually tightened till they cease to revolve, when the car will, of course, travel at the same rate as the cable. Ample break-power must be provided for *gripping* the rails on each side in the case of gradients which are steeper than 1 in 6. In hauling a locomotive up anything steeper than 1 in 20, a special truck must be provided to carry it in such a position as to prevent the water running off the top of the fire-box or uncovering the tubes.

**Toothed Centre Rail.**—This is usually composed of three steel plates, each ¾ inch thick and 4½ to 5 inches deep, carried by cast-iron pedestals, which are fastened to the sleepers. The teeth, which should be about 2 inches deep and 4 inches pitch, ought to break joint, as is shown in Fig. 77, to render the working regular. Experience has shown that this rack would be strong enough for an engine weighing 42 tons to take loads of 120 tons up a gradient of 1 in 16·5 at a speed of 5 miles an hour.[1]

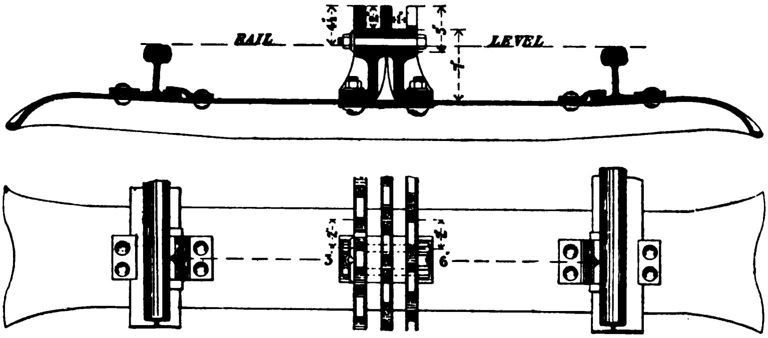

FIG. 77.

The Abt locomotives employed in connection with the racks usually consist of two distinct engines, one on the ordinary adhesion principle, and the other with gearing to work up the steep gradients where the centre rail is necessary.

When the gradient is steeper than 1 in 20, a special arrangement to prevent the water getting off the top of the fire-box is necessary as before.

**Centre-grip Rail.**—This is illustrated in Fig. 78, where it will be seen that a double-headed rail is laid horizontally at the centre of the track a little above the regular rail-level, to enable a pair of horizontal driving-wheels in the specially made Fell engines to grip it firmly. When the steep incline is reached, and the horizontal wheels have gripped the rail, the steam is admitted to the cylinders working them, and, unless the supply is ample, shut off from those working the adhesion drivers. This was used on the original Mont Cenis Railway, where there were gradients of 1 in 12, but has to a great extent been superseded by the Abt rack-rail system, although it is better adapted to curves of less than 5-chains radius.

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[1] *Proc. Inst. C.E.*, lxxxviii. 491.

**Gas and Compressed Air.**—Gas is usually applied through the medium of petroleum, and no provision has to be made for it in the construction of the line. For compressed air a supply-pipe is necessary, and stations for getting a fresh quantity must be fixed at regular intervals along the line, these in the case of street lines being situated in brick pits, protected by hinged iron covers like hydrants. Neither gas nor compressed air has been much used as a motive power for this purpose, however.

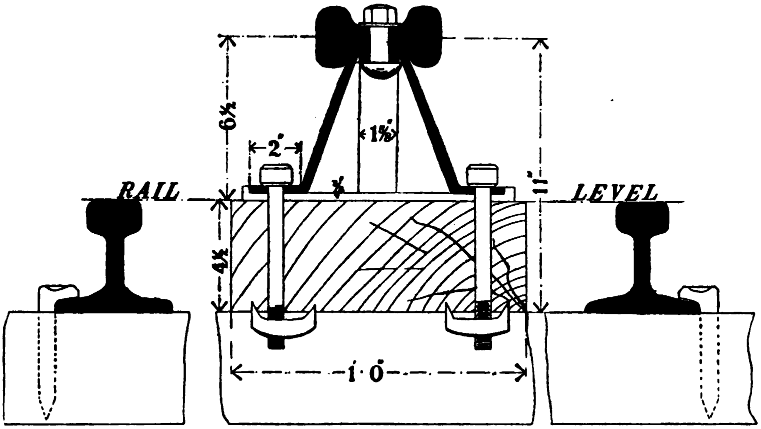

FIG. 78.

**Electricity.**—Electric motors take up so little room that they can be conveniently applied to every axle of a train, and as there is no question of burning the tops of the fire-boxes as in the case of steam locomotives, any gradient up to 1 in 6 can be ascended by simple adhesion without any complication. The equipment costs a good deal of money, and unless the traffic is very heavy, it is not economical to work an ordinary light railway by electricity, especially if there is much goods traffic, for every coal and cattle waggon could hardly be fitted with a motor. In the case of a line, however, where the gradients are not worse than 1 in 14, and the goods traffic is not heavy, mixed trains could be run with the motors on the axles of the passenger carriages only.

For a tramway or suburban railway service in a large town electricity is a most convenient power, even when the gradients are easy. The large engines used for generating the power only burn 1½ lbs. of coal per horse-power per hour, as compared with the 7 lbs. of a locomotive, and where there are frequent stops, the quick starting-power of the motors is a great advantage. The power is generated at a central station, and conveyed to the sub-stations by underground cables, and supplied to the motors by an insulated central rail or overhead trolley wire at a pressure of usually 500 volts, the return being by the running rails. The trolley wires are usually fed from the cables at half-mile intervals, each half-mile being capable of being cut out without the rest of the working being disturbed, its only connection with the next sections being through the switch-boxes placed, in the case of a tramway, in a pillar on the kerb-stone.

When a line gets beyond a certain length, to save the expense of a large cable and return wire, which would be necessary if the rails were of insufficient area to carry the current, it is usual to generate the current at a high pressure, and to transform it down to 500 volts at sub-stations.

The alternating high-pressure current is conveyed to the sub-stations, where it is brought down to a lower pressure by means of statical "transformers," and converted into a continuous current by means of a "converter."

The diagram (Fig. 79) will give some idea of the arrangements. The electricity is generated by the dynamos at **A**, in the form of an alternating current. It is transmitted by an underground cable at a pressure of 5000 volts to the sub-station **B**, where it is transformed to a pressure of 500 volts, and converted into a continuous current.

The continuous 500-volt current flows along the main supply feeder **DE**, and from the point **B** the action is the same as if the electricity had been generated at 500 volts pressure, and fed direct into the mains from the dynamo. By means of switch-boxes, placed half a mile apart, a portion of the current in **DE** can be taken by the trolley wire **HK**, arrangements being made so that the whole can flow along **DE**, or the whole along **HK**, as well as part along each, to allow for cutting out any one section in case of repairs being necessary.

At **K** the current passes through the motor to **M**, whence it flows back by the running rails by **L** to **B**. The number of cars that can be worked depends on the volume of current in the wire. Supposing this was 160 amperes, and each car was taking 16 amperes, ten could be run at once, and, unless the trolley wire was small in proportion to the main, several could be worked on each half-mile section at the same time.

The reader who wishes for more information on this subject is referred to Slingo's "Electrical Engineering," Joyce's "Examples in Electrical Engineering," Carus' Wilson's "Electro Dynamos," and the following papers in the *Min. Proc. Inst. C.E.:* "Dublin Electric Tramways," vol. cxxxiii. p. 174; "Electrical Equipment of the Waterloo and City Railway," vol. cxxxix. p. 56; "Electrical Traction on Railways," vol. cxlix. p. 40.

A list of the various units used in electrical measurements is given in Appendix U, with a short explanation concerning them, and in the same appendix is given a table of resistances.

As the Board of Trade will not allow a greater current than 2 amperes, nor a greater drop in potential than 7 volts in the earth, it is necessary to make the rails carry almost all the return current, and so the joints must be made good, with copper bonds to secure this. The sectional area of the copper bonds should be one-sixth that of the rails, and the surface in contact must be equal to the sectional area of the rails. These bonds must be long enough to clear

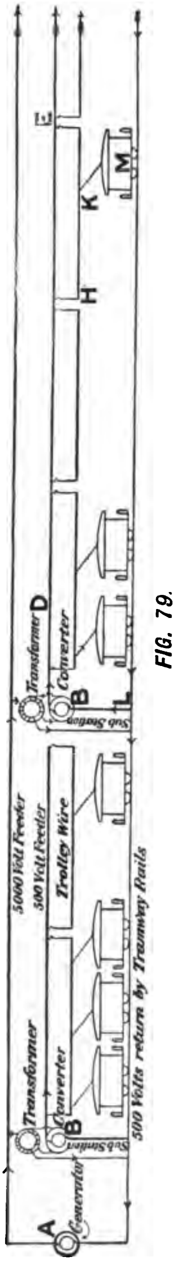

FIG. 79.

the fish-plates and crossings, etc., where there is any junction work.

The poles for carrying an overhead wire are usually made up of three tubular pieces telescoped into each other, with 18-inch laps. The larger tube is shrunk on to the smaller one, and some amount of ornament, which in no way increases the strength, is generally added, since in a town the bare pole would present a very offensive appearance.

The poles, to carry the trolley wire 21 feet above the level of the street, are usually 31 feet long, 6 feet in the ground, and 25 feet out. They should be of the dimensions and stand the tests given below, the heavier pole being for sharp curves, or other situations where the strain is great.

| | Length. | Light pole. | | Heavy pole. | |
|---|---|---|---|---|---|
| | | External diameter. | Thickness. | External diameter. | Thickness. |
| Bottom tube . | 17 feet | 8 inches | $\frac{1}{2}$ inch | $9\frac{1}{4}$ inches | $\frac{5}{8}$ inch |
| Middle „ . | 9 „ | 7 „ | $\frac{7}{16}$ „ | 8 „ | $\frac{1}{2}$ „ |
| Top „ . | 8 „ | $6\frac{1}{8}$ „ | $\frac{3}{8}$ „ | 7 „ | $\frac{3}{8}$ „ |
| | | Pressure. | Deflection. | Pressure. | Deflection. |
| Temporary deflection test | | 700 lbs. | 6 inches | 1000 lbs. | 6 inches |
| Permanent „ „ | | 1200 „ | $\frac{1}{2}$ inch | 2000 „ | $\frac{1}{2}$ inch |

In testing the deflection the poles must be firmly held at the lower end, and 6 feet from it, and the pressure applied at 18 inches from the top. In addition to these tests the poles must not show any signs of telescoping or failing in any other way when dropped endways several times on to a solid base from a height of 6 feet.

The poles should be firmly fixed not more than 40 yards apart, at such an angle as to ensure their not being out of the vertical when they are under stress, for they look very unsightly if they bend over ever so little. To fix them firmly, the holes excavated to place them in should be filled up with concrete. These holes, which must necessarily be nearly 2 feet in diameter, whatever the nature of the ground may be, should in some cases be as much as 4 feet square.

The trolley wires from which the cars take their current should be of hard drawn copper, with 98 per cent. of conductivity, and be capable of sustaining a stress of 25 tons per square inch. The most satisfactory size has been found to be No. 3/0 S.W.G., which gives a diameter of 0·372 inch, and a sectional area of 0·109 inch. According to the Board of Trade regulations, they must be at least 17 feet above the level of the street, but it is usual to put them 4 feet higher where cars with top seats are employed.

Each trolley wire must be protected from falling telegraph or telephone wires by two guard wires placed 2 feet above it and 8 inches away, one on either side. If the trolley wires are not more than 3 feet apart, three, or, if they are not more than a foot apart, two guard wires are, however, sufficient. In some cases cross wires or netting may be necessary. These wires should be of galvanized steel of No. 7 S.W.G., or, better, of seven strand (each wire of which is No. 14, or 0·08 inch diameter).

The trolley and guard wires are sometimes carried by a span wire instead of on a bracket, and occasionally these span wires are fastened to buildings. They should be the same size as the guard wires, and, like the trolley wires, be strained to 700 lbs. tension.

The feeders are insulated by paper $\frac{1}{8}$ inch thick, and covered by a lead sheath $\frac{3}{16}$ inch thick. It is often convenient to lay them in fire-clay pipes below the track, and to have manholes 4 to 8 feet square and 6 feet deep to give access.

In the case of a railway which can be properly fenced off, the conductor may be laid on the surface between the rails. In this case a steel [|, perhaps 4 × 2 × $\frac{3}{4}$ inches in size, is provided, and supported on porcelain insulators, which are fixed to the sleepers, and, to allow for the places where this must necessarily be broken to clear level crossings and junction work, two slipper collectors are fixed, one at each end of the car, so that one may always be in contact. This may be divided into very short sections, each of which, by means of a switch acted on by an electro-magnet on the car, can be made "alive" only when the car is passing over it.

# CHAPTER XIII.

## *CONTRACTS AND SPECIFICATIONS.*

**Tenders—Hints as to general specifications—Form of contract—General clauses—Specification — Ballast — Sand — Lime — Cement — Bricks—Stone—Timber—Piling — Concrete — Mortar — Brickwork — Masonry — Centring — Puddle—Pitching—Asphalt—Ironwork—Steel—Cast iron—Painting—Drain-pipes—Permanent-way materials—Fencing—Earthworks—Ballasting and laying the permanent way—Maintenance of way—Water-pipes—Tunnelling—Bill of quantities.**

THE settlement of a contract is a matter for the solicitors, but the general conditions, specification, form of tender, and advertisement must be drawn up by the engineer, at any rate in the first instance.

In some cases it may be advisable to arrange the contract by private negotiations, but it is generally the rule to ask for tenders from contractors, either by advertising or by issuing private invitations.

The advertisement or private notice should be in the following form:—

——— LIGHT RAILWAY ORDER, 1902.

Tenders are invited for a single line of railway about ——— miles in length, from ——— to ——— in the county of ———. The following are some of the chief items in the quantities:—

| | |
|---|---|
| — Yds. Cube Excavation | — Yds. Lin. Tunnel (single line). |
| — „ „ Concrete | — „ „ Permanent-way Materials to be supplied and laid. |
| — „ „ Brickwork | |
| — Feet „ Timberwork | — „ „ Post and Wire Fencing. |
| — Tons Steel Girders | — „ Super Granite Pitching. |

The general conditions, specification, plans, and quantities may be seen at the office of the engineer, ——— at ———, between the hours of 10 a.m. and 4 p.m. any day between the ——— and ——— days of ———, and copies of the quantities and form of tender may be obtained on deposit of the sum of Five pounds, which will be returned only to contractors, who have sent in and not withdrawn *bonâ fide* tenders, as soon as the contract has been signed.

Tenders to be in my hands by 10 a.m. on Wednesday, the ——— instant. Neither the lowest nor any tender will necessarily be accepted.

———,
**Secretary's Office,**
**——— Light Railway.**

**———, 1902.**

It is right to give the principal items in the quantities in the advertisement, as has been done in this form, so as to save contractors the trouble of going to see the plans when the work is of a nature that they do not care to undertake.

Contractors in tendering should fill in the following form, which should be supplied to them with the general conditions, specification, and quantities (the latter in duplicate):—

— LIGHT RAILWAY ORDER, 1902.

"We, ——— of ———, hereby undertake to construct the railway from ——— to ———, in the county of ———, and other works in accordance with the general conditions, specification, quantities, and drawings attached or referred to for the gross sum of ——— pounds (£ ), and to complete the same to the satisfaction of the engineer within —/—— months of the date of contract; and should our tender be accepted, we agree to execute a contract based on the general conditions, specification, and this tender, and if called upon, to procure two sureties, to the amount of ———, who shall also execute the contract.

———."

It is desirable, to save time and confusion, for an engineer to have a standard form of General Conditions printed, and he can modify this to suit any contract by making the alterations that may be required on the first and some of the last few pages. The specification under which the work is to be done should also be printed, and so far as it is possible be the same in every case. In the contract, which is prepared by the solicitors after the tender has been accepted, the general conditions will often be somewhat modified, and it is necessary for the engineer to take a note of the variations.

The general conditions and clauses in the specification may conveniently be arranged in the following order:—

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9. Notices, Fees, Mode of dealing with adjacent property, Temporary roads and fencing . . . . . . . . . 152
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11. Explosives, Magazines, and Licences . . . . . . . 153

12. Contractor's representative . . . . . . . . . . 153
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19. Setting out and correcting errors . . . . . . . . 155
20. Copies of the drawings . . . . . . . . . . . . 155

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Excepting 1, 2, and perhaps 35, these clauses are not likely to require altering, except in special cases. Such things as slating, glazing, plastering, and the like, can be fully described in a few words in the schedule of prices, and so do not require any notice in the specification, especially as they are covered by the general terms in clause 5; and where a bill of quantities is provided, it is not necessary to fully describe all the different works in the specification, as doing so simply means so much repetition, unless the quantities do not make it clear where the different items are situated.

The specification should be so worded as to make it quite clear what is intended, and should as far as possible protect not only the company, but also the contractor, from any unfair treatment. It should be understood that the clauses are to be rigidly enforced, so that a stranger tendering may be on equal terms with those who are acquainted with the engineer's practice. There should be no misunderstanding as to the quality of the workmanship and material that is to be employed on the works or the money that is to be paid, so far as is possible.

It is generally fairest to arrange a contract on a bill of quantities, and to make additions or deductions as these are exceeded or the reverse; but in some cases it is possible for the exact amounts to be agreed, and a lump-sum contract arranged accordingly, the contractor taking the risk of the accuracy of the quantities.

In some cases it may be necessary for the contractor to buy the land, provide the accommodation works, pay all claims in connection with severance, ancient lights, etc., interest on capital, and the like; but in such a case the general conditions would probably require considerable modification.

## CONTRACT FOR THE CONSTRUCTION OF A RAILWAY FROM ——— TO ——— FOR THE ——— LIGHT RAILWAY COMPANY.

### GENERAL CONDITIONS.

1. This contract comprehends the supply, delivery, erection, and fixing of all materials, labour, plant, water, lights, firing, tools, implements, timbering, staging, scaffolding, machinery, and all other matters which may be required for the entire construction, completion, and maintenance for six (6) months after completion of a railway from ——— to ———, as shown on the accompanying drawings, and other works in connection therewith, whether temporary or permanent, and also of any extra works which may be ordered by the engineer to be carried out which are not situated at a greater distance than two (2) furlongs from the centre line of the said railway.

2. The following words wherever used herein shall, unless it is obvious to the contrary, have the meaning hereby ascribed to them, viz. :—

*The Works.*—The railway which is to be constructed, and the works in connection, and the extra works which may be included in this contract.

*Company.*—The ——— Light Railway Company.

*Engineer.*— ——— of ———, or the chief engineer of the ——— Light Railway Company for the time being.

*Contractor.*— ——— of ———, and all or any one of the partners in ——— firm, and his or their executors, administrators, and assigns, and any receiver or trustee in bankruptcy or under a deed of composition with creditors.

*Best Workmanship and Materials.*—Workmanship and materials of such a quality that there is nothing superior obtainable.

The singular shall everywhere herein also include the plural, and the plural the singular.

3. The works are to be carried out in all respects under the control, instructions, and directions, and to the entire satisfaction, of the engineer and his representatives, who shall have free access at all times to the works and to any place where ironwork or other materials are being manufactured for use on the works. They shall be at liberty to inspect and test the quality of such ironwork

and materials, and of all other materials intended to be used at the expense of the contractor, who shall without charge provide all necessary test-pieces, labour, and appliances, or repay to the company all the expenses to which they may be put in getting the testing carried out elsewhere.

4. These general conditions and the specification, together with the drawings and quantities, shall be interpreted according to the fair evident meaning of the same, notwithstanding any legal or other informality which may exist in the wording or otherwise.

5. All materials and workmanship shall be the best of their respective kinds, and the engineer shall have power to require the immediate removal of any work or materials that may in his opinion be inferior; and should the contractor fail to do so, the engineer may himself remove, or cause to be removed, such work or material, and charge the contractor with the cost of so doing, which charge shall be deducted from any moneys which may be due to him; or the engineer or his representative may entirely suspend the carrying out of the works until the work or materials he objects to has been removed, and no work which is carried out after he has instructed the contractor to suspend work will be paid for; or, if the engineer prefers, he may be at liberty to deduct from the amount that would have been due to the contractor, if materials or workmanship of the kind specified had been used, such a sum as in the engineer's opinion represents the difference in value between the materials or workmanship actually used and those of the kind specified.

6. All materials, plant, and other matters that are brought by the contractor from time to time on to the site of the works or on to land belonging to or in the occupation of the company, and the rights in every means of access to the works, shall immediately become the absolute property of the company, unless the same are not approved of by the engineer, and the contractor shall have no right to use the same except for the purposes of this contract; but if the works be duly completed, and if there is no debt owing to the company by the contractor, the company will on completion give the said materials, plant, and other matters not used in or required for the completion or maintenance of the works to the contractor, as part of the consideration for the performance of the contract, and the contractor shall immediately remove the same from the company's property, and the company shall not be

responsible for any loss, destruction, or damage to any such materials, plant, and other matters arising from any cause whatsoever; and further, the contractor shall not bring on to the company's land any materials that are not required for this contract.

7. Should the contractor become insolvent or bankrupt during the progress of the works, or before the expiration of the term of maintenance, or should it appear to the engineer that the contract is not being carried out in a proper way, or with proper materials or workmanship, or with sufficient diligence, or in accordance with the terms of the specification or these general conditions, he may serve the contractor with a notice relating to his complaint; and if the contractor does not within 7 days after the delivery to him of this notice proceed with the work in a proper manner, or remedy the defects in the carrying out of the same, and conduct the work to the entire satisfaction of the engineer, the company shall have power, after having given 48 hours' notice in writing, to discharge the contractor from the works and employ workmen and others to complete the same, and to enter into a contract or contracts with any person or persons to execute and complete the same for such price or prices as may be agreed upon between the company and such person or persons, and the contractor shall be liable for and pay to the company any sum or sums that the company may expend in completing and maintaining the works beyond the amount that would have been due to the contractor had he satisfactorily completed and maintained the whole works. And in the event of the company giving such notice to the contractor, then they shall have power by themselves, and their agents, servants, or other persons authorized by them, to take possession and to hold all materials, horses, plant, tools, implements, buildings, scaffolding, machinery, and other matters on the works, or on property owned or occupied by the company, and to keep and employ the same in the further execution of the works or any part thereof until the completion of the said works, without the company being bound to make any compensation to the contractor for the use or employment thereof, or for wear, tear, destruction, or consumption.

All notices shall be deemed to have been delivered if they have been left with the contractor or his foreman, or delivered at his office on the works, or posted in some conspicuous place on the works.

8. From their commencement to the expiration of the term of maintenance, the entire responsibility and care of the works shall rest with the contractor, who at his own cost shall make good and restore any portions which may fail from any cause whatsoever, or which may be lost, stolen, or injured, and shall indemnify the company against all claims and demands, and all costs, charges, and expenses to which it may become liable, arising out of or directly or indirectly attributable to any accident which may occur by reason of the failure of any of the works, whether temporary or permanent, or of the negligence or incompetence of any of his servants, agents, or workmen; and in the event of his neglect or refusal to pay such claims, they shall be recoverable against him as ascertained and liquidated damages, and may be deducted from any moneys that may be due to him, but, without relieving the contractor of his liability under this clause, if the engineer should think any timbering, staging, scaffolding, shoring, hoarding, fencing, watching, or other matter insufficient or insecure, he may require the same to be made good, and the contractor shall at once make good the same; and in like manner every precaution required by the engineer shall be taken to prevent the movement of the ground and buildings; and when the engineer considers it necessary the contractor shall insure the buildings and materials against fire in the joint names of himself and the company in an office approved by the engineer, with whom the policy shall be deposited.

If during the progress of the works, or within the time during which the contractor has to maintain the same, any imperfection shall appear in any part of the works, from whatever cause such imperfection may arise, and notwithstanding any order or recommendation or certificate which may have been given to enable the contractor to obtain payment for work supposed to have been properly executed, it shall immediately be repaired and made good at the contractor's expense; and the granting of a certificate by the engineer for a payment of money shall not be taken as evidence of his approval of the workmanship or materials used, or as a waiver on the part of the engineer or company of any of the conditions of the contract.

9. The contractor shall, in the first instance, give all necessary notices to the local authorities and other persons, companies, corporations, and commissioners, and shall obtain the necessary licences, and pay all fees. He must secure the safety and continuous

use of all walls, buildings, fences, roads, footpaths, railways, tramways, rivers, canals, docks, gas hydraulic and water pipes, and wires, and generally of all public and private property adjoining, near to or affected by the works, and on completion of the same, restore all property to the same state in which it was before it was interfered with; or where any authority, company, or person thinks proper to do any work incident to the contract themselves, the contractor shall pay all charges and expenses of so doing, and these may be recoverable by such authority, company, or person from the contractor; and should he fail to pay such claims, the company may themselves pay the same, and deduct the amounts from any moneys that may be due to him or may recover the same from him in the manner before mentioned. The contractor must also provide and maintain all temporary crossings, bridges, road diversions, fencing, and other matters that may be necessary for the execution of the works within the time specified.

10. The works shall be carried out in conformity with the various Acts of Parliament affecting them in force at the time of their execution, and the special Acts and Orders authorizing their construction.

11. Where explosives are used for blasting, the contractor must provide proper safe magazines so that accidents may so far as possible be avoided, and he shall take every precaution to prevent explosives from being brought or suffered to remain on the works unless they are in suitable cases made of moderate dimensions and of suitable form with covers; and in blasting no dangerous means must be resorted to. The contractor is to take all necessary steps to provide licences for any magazines that he may erect upon or near to the lands of the company, and shall in all respects observe the provisions of the Explosives Act, 1875, and of any other Acts or amendments thereof that may exist or be made.

12. The contractor shall not absent himself from the works unless he leaves a fully authorized and experienced agent to act in his behalf in his absence, and to whom instructions may at all times be given.

13. All men employed by the contractor or any sub-contractor for a part or the whole of the works are to be paid in cash every week at the least in an office or offices to be erected for that purpose, and in the event of his failing to so pay them, the company

may advance the money to the men, and charge the contractor with the amount in the manner before mentioned.

14. The contractor will be required to pay the costs of any police which the local magistrates may appoint in connection with the execution of the works. He shall take every possible precaution to prevent the introduction and spread of disease, the disturbance of law and order, and all annoyance to the owners and occupiers of premises in the neighbourhood of the works by reason of trespass or any other cause.

15. The engineer shall have power to require the contractor to remove any person employed by him about the works without assigning any reason for so doing, and the contractor shall remove such person within 24 hours after the receipt of the order to do so.

16. No part of the works shall be sublet without the permission of the engineer in writing, and such permission shall be revocable if it should appear to the engineer that the sub-contractor is acting or carrying out the work in an improper manner.

17. The works are to be carried out in conformity with the drawings given in the schedule of drawings and the written dimensions and descriptions or instructions thereon, and also in accordance with such other drawings as may be furnished from time to time by the engineer; but should it become necessary in the opinion of the engineer at any time to increase, diminish, or alter the form or dimensions of any part of the works, the contractor shall comply with any order he may receive from him to that effect in writing. The additions, diminutions, or alterations will be allowed for or deducted at the rates given in the attached priced bill of quantities, or, where the same does not apply, at such rates as the engineer may consider fair and reasonable, and the general contract shall not be annulled or vitiated thereby. The works are also to be carried out in conformity with the terms of the specification, these general conditions, and the bill of quantities. The figures put in the bill of quantities are in no way guaranteed, but the contractor will be paid according to the amount of work he actually executes. The contractor shall not undertake any other contract within the area covered by the works until the works are complete and the period of maintenance has expired, unless he first obtains the written consent of the company to do so in every case.

18. Should any discrepancy or ambiguity exist between the scale attached to the drawings and the written dimensions thereon,

or between the drawings and the specification, or between the drawings or specification and the features on the site, the same is to be referred to the engineer, whose decision shall be final, and anything contained either in the specification, quantities, or drawings alone shall be as binding on the contractor as if it was contained in them all. The written dimensions are to be taken in preference to scaled dimensions, unless the error is obvious, or unless the engineer otherwise directs.

19. The contractor will be responsible for the true and perfect setting out of the works in correct position and level, and for the forms and dimensions of all parts of the works, and all errors either in the setting out or execution of the work are to be corrected at the contractor's expense. Any setting out that may be done by the engineer or his assistants, or any lines or levels that may be given by him or them, will not in any way relieve the contractor from this responsibility, unless he has pointed out in writing to the engineer before the particular work is put in hand that an error in the setting out has been committed.

20. The contractor must provide at his own expense copies of all drawings required for the execution of the works.

21. Payment will be made monthly on the engineer's certificate, which will be based on his estimate of the value of the work done, to the extent of ninety (90) per cent. thereof. The remaining ten (10) per cent. will be retained until the works are certified by the engineer to be complete in all respects, when one-half of this will be paid, and the remainder will then be retained until the expiration of the term of maintenance; but no certificate will be given unless the contractor has done work to the value of at least £500 since the granting of the last certificate, except in the case of the certificates issued on the completion of the works and on the expiration of the period of maintenance.

22. The contractor shall not be entitled to interest on any balances which may on the final settlement of his account be found to be due or to have been due to him at any other time, unless payment on the engineer's certificate shall have been delayed more than 14 days from the date thereon, in which case interest at the rate of five (5) per cent. per annum will be allowed on the money due under such certificate for the time beyond the 14 days to the date when payment is made.

23. The engineer shall give notice to the contractor when he

requires any part of the work to be measured, and the contractor shall accompany and assist him, so that the quantity of work may be agreed to upon the spot; and if after such notice the contractor shall fail or neglect or refuse to attend, the engineer's measurements shall be final and binding.

The contractor must call upon the engineer to measure any foundation or other work that may be about to be covered up or hidden from view before it be covered up or hidden, and should it be covered before such measurement be taken, the contractor shall open out the same at his own cost.

All measurements will be taken according to the nett dimensions of the respective work when finished, notwithstanding any custom that may exist to the contrary, but if the dimensions shown upon the drawing or required by the instructions given by the engineer shall have been exceeded, the measurement shall be taken as it appears in the said drawing, or as directed to be made in the said instructions. No allowance extra will be made for circular work or any labours beyond what is given in the bill of quantities, but provision in the prices must be made for all contingencies. The contractor is referred to the clauses dealing with the different classes of work for the manner in which these will be measured, and for any exceptions that will be made to the terms in this clause.

24. The contractor will be refunded the actual amount paid for all additional materials ordered to be supplied for which there are no prices in the schedule, with an addition of ten (10) per cent. In making application for payment for the same the contractor must produce his accounts showing the actual amounts paid by him, and he will be allowed the benefit of any cash discount allowed to him, provided the same does not exceed two and a half (2½) per cent.

25. An account of such work as the contractor has been directed to perform by day-work shall be forwarded to the engineer every week for work done in the previous week, and in default thereof the contractor will not be entitled to any payment for the same. No allowance will be made in the day-work for the use of the contractor's scaffolding and plant, nor for any timekeepers, clerks, foremen, and others, but the nett time only of the men, horses, or boys actually working will be taken and paid for, and no day-work is to be done except by an order from the engineer in writing.

26. The contractor shall send in an account for all the work he

has executed for which there is no provision in the schedule of prices every month, and no claim for payment for the same will be allowed, and no claim for an extra of any description will be considered if it is not made within a month of the time when the work was executed.

27. The contractor shall keep the engineer informed in writing as to what arrangements he proposes to make in the carrying out of the works and when and where the different materials are being manufactured, and he shall also give monthly returns of all the men, horses, and plant employed on the contract and of all accidents that may have occurred.

No work shall be done on Sunday, except such as cannot be done on a week-day.

28. The works shall be commenced within a month of the date of the signing of the contract, and completed in all respects within the time named in the tender, and should the works not be completed within such time, the contractor shall pay the sum of ten pounds (£10) per day for each and every day after that time that the works remain incomplete, which sum shall be regarded as ascertained and liquidated damages, and not as a penalty, and shall be deducted from any moneys that may be due to the contractor.

29. An extension of time will be granted for any extra works that may be ordered, such as will in the engineer's opinion be sufficient for the execution of the same, and the engineer may remit the whole or a portion of the said sum if he is satisfied that the contractor has made every effort to get the works finished in the contract time.

30. The company will provide from time to time all lands required to be occupied permanently for the works, but the contractor must provide at his own costs, in all respects, any further quantity of land which he may require for temporary purposes or for access to the works. The company will put the contractor into possession of the land as and when it acquires the same, but the contractor shall have no claim against the company for the consequences of any delay in obtaining possession. An extension of time for completion will, however, be granted by the engineer should he consider it necessary in consequence of delay in obtaining possession of the lands. The company will pay compensation to the landowners, lessees, and occupiers for the land they purchase

and occupy for the permanent works, and settle all claims for ancient lights, rights of way, and permanent diversion of water, but the contractor must settle all other claims due to the execution of the works.

31. The company shall be at liberty to employ other contractors and persons on the works, and the contractor must convey all rolling stock, telegraph poles and materials, signalling apparatus, electric traction apparatus, and machinery and building and other materials, and scaffolding and plant of all kinds, at a fixed price per ton, as provided in the bill of quantities, which price shall include the use of the contractor's temporary road and junctions with the existing railway and the permanent way, and all hauling, unloading at the points directed, and returning of empties and all other items of expense. Each truck must be unloaded and returned within 30 hours of the receipt of the advice note by the contractor, and the contractor will have to pay the demurrage thereon in default of this. Should the engineer consider that the work of the contractor is being seriously interfered with by such other contractors or persons, he may grant such an extension of time and monetary compensation as in the engineer's opinion is sufficient if the contractor applies for such extension and monetary compensation within a week of the interference taking place.

32. The engineer may regulate the rate of progress of the whole or a portion of the works, and may entirely suspend or stop the same in case of need. Any claims the contractor may have for compensation on this account shall be made week by week, and the engineer will allow what seems to him to be fair and reasonable. Should the whole of the works be stopped by the engineer's orders for three months, or should payment of any certificate be delayed more than a month, the contractor may claim to have the work he has done measured up as if the works had been completed, but he shall not be entitled to make this claim or to receive any compensation if the notice has been given under the provisions contained in clause 5.

33. All buildings, trees, and other matters on the land provided by the company shall be considered to be their property unless it is otherwise specially stated in the specification or the bill of quantities. Nevertheless, the contractor may employ for use on the works any soil, ballast, sand, or building stone that may be approved of by the engineer, but he shall not sell or remove

the same for any other purpose, and he shall only take the same from such positions as the engineer may approve, and must at his own expense fill up all excavations which he has made in getting such soil, ballast, sand, or building stone with sound material, and well ram and consolidate the same.

No advertisement shall be put on any part of the works except with the written consent of the engineer.

34. On the completion of the works the contractor shall clear away all plant, materials, waste, rubbish, and other matters, except such as are required for the maintenance of the works, and leave the whole neat and clean and in a workmanlike condition.

35. The works are to be maintained and kept in repair for the space of six (6) months after the same have been accepted by the engineer as complete, and all deficiencies that may be observed during such time shall be made good before the engineer's final certificate will be given.

36. The contractor must satisfy himself as to the nature of the ground and foundations, the means of access, and other accommodation he may require, and generally as to all matters which can in any way influence his tender; and no information on such matters derived from the drawings or specification, except such as can be obtained only by reference to the drawings or specification, and not by examination or inspection of the circumstances themselves, and no information obtained from the engineer or his representative, will relieve the contractor from any risks or from the entire fulfilment of his contract.

37. The contract includes all incidental works and details not particularly mentioned in this specification, but which, whether in the temporary or permanent works, must evidently be required in the fulfilment of the contract; and the contract sum must include all workmanship and materials necessarily implied in or connected with the due and proper completion of the work, as described in or to be inferred from the drawings or specification, and the contract sum is to cover the same, although they may not be included in the bill of quantities.

38. No free passes will be granted, and the carriage of all material over the company's railway must be paid for, and all materials and plant shall be sent over as much as possible of the company's line, unless this is obviously unreasonable.

39. In the prices given in the schedule allowance must be made

for supervision, watching, lighting, and all temporary roads, bridges, fencing, and other matters, and the maintenance of the same, and also for the making good of all roads, bridges, and other things injured or affected by the works, and for all other things mentioned in these general conditions, except as to the unloading of other persons' goods, to which a price must be given.

40. All disputes and differences relating to matters connected with this contract which arise during the progress of the works shall be settled by the engineer, whether acting as valuer, arbitrator, or otherwise, who may for the purpose of making such decision proceed in such manner as he thinks fit, without a formal submission and without hearing witnesses, and he may inform himself as to the case through the oral or written statement of any party, or may decide the matter on his own knowledge, inspection, or calculation, and may state his decision verbally or in writing or in the form of a certificate in lieu of an award.

41. Should the contractor be dissatisfied with the decision of the engineer respecting any point, the same shall be referred to an arbitrator to be appointed by the President of the Institution of Civil Engineers for the time being, on the contractor's making a written application during the period of maintenance; and such arbitrator's determination, decision, or settlement shall be final and conclusive and without appeal, and no claim or action shall be made or brought or maintained except upon and for the purpose of enforcing his determination, decision, or settlement.

## SPECIFICATION.

42. **Ballast and Sand.**—The ballast and sand shall be perfectly clean, and free from clay, loam, and other foreign matters. No stones shall be more than 2½ inches in size any way nor less than ½ inch. The sand shall be sharp and coarse, and must be washed if found to be at all dirty. No ballast or sand that will not perfectly satisfy the engineer and these conditions will be allowed to be used, whatever the cost may be of getting the same. By the term "ballast" is meant the mixture of stones and sand in such proportion as may be approved by the engineer. Clean furnace ashes may be used instead of sand if desired.

43. **Lime and Cement.**—The lime shall be of the very best quality of that known as "Blue Lias," freshly burnt.

The cement shall be of the very best quality, and shall be obtained from the Thames and Medway district, or from other manufactories which may be approved of by the engineer. It shall be well burnt, and weigh from 112 to 116 lbs. per bushel when filled from a hopper 12 inches above the measure. For the purpose of ascertaining the weight, the cement shall not be shaken or put under pressure, and the surplus shall be struck off when the measure is full. It shall be of such a fineness that the residue on a screen of 2500 meshes to the square inch, *i.e.* of 50 to the lineal inch, shall not exceed 5 per cent. The neat cement must not in any weather set in less than an hour. It shall sustain a direct tensile stress of 350 lbs. per square inch after having been made 7 days, and placed under water for 6 of these, and of 150 lbs. when mixed with three times its weight of dry sand which has passed through a sieve of 400 meshes to the square inch. Pats of neat cement not more than ¼ inch thick shall not show signs of cracking. It shall be spread out on a wooden floor for a week before it is used, and turned over three times during the week, and when it is mixed with water for testing, the temperature shall not rise more than 3° Fahr. Samples for testing shall be taken from each consignment, and should these fail to satisfy the above tests, the whole consignment will be rejected. This testing will not, however, in any way free the contractor from his liability to restore any work which may fail owing to a defect in the cement.

44. **Bricks.**—All the bricks used shall be of uniform size, square, sound, hard, well burnt, and well shaped, made from good brick-earth, properly ground and tempered, and free from lime, salt, and other injurious matters. For the face-work all the bricks shall be of uniform colour, with the faces straight and square, and be free from chips and cracks. In certain cases the face will be formed of brindled bricks from the Staffordshire district. The bricks shall be of such a size as to make in the work with the mortar joints 9 inches × 4½ inches × 3 inches. If larger are used, the extra size, not being required, will not be paid for; but if smaller are allowed to be used, the same shall be measured, and a deduction made accordingly. All copings, kerbs, and the like shall be of the best quality, regular in shape, and free from chips and cracks. No bricks shall be used samples of which show signs of being injured after having been saturated with water and placed for an hour in a temperature of 20° Fahr. and under a load of 336 lbs. per square inch, or which separate

from the cement mortar, mixed as specified hereafter, after having been set for 7 days, under a tensile stress of less than 10 lbs. per square inch.

45. **Stone.**—Blue Pennant, York, Derbyshire, or other approved and equally good stone shall be used for all girder-beds, strings, copings, caps, and facework. All ashlar imposts, arch-springers, skew-backs, quoins, strings, copings, and caps shall be accurately worked to the drawings, fair tooled on the face, and boasted true on the beds and joints. All oversailing stones are to be throated. Every stone shall be of the full size shown on the drawings, and the divisions between stones shall only be made where they are indicated on the drawings. All stone for whatever purpose shall be of a hard, durable nature, and obtained from quarries where it has been proved to be so.

No stone shall be used that will not satisfactorily stand the tests specified for the bricks.

46. **Timber.**—The whole of the timber work, except where otherwise specified or ordered by the engineer, is to be of Memel or pitch pine. All timber shall be thoroughly seasoned and free from sap, shakes, splitting, large and dead knots, and all other defects.

When creosoting is specified or ordered, 8 lbs. of creosote, or 4 lbs. in the case of pitch pine, shall be forced by Bethel's process into each cubic foot of the timber after it has been sawn, morticed, tenoned, and fitted together; or, if tarring is specified or ordered, two coats of Stockholm tar are to be laid on to the timber boiling hot.

When the timber has been put into the tanks the creosote shall be raised to a temperature of from 212° to 220° Fahr., and the moisture drawn off by an air-pump. The creosote shall then be allowed to cool, and a pressure of at least 15 lbs. per square inch over the atmospheric pressure shall be maintained for 6 hours.

All oak to be of English growth.

47. **Piling and Carpenter's Work.**—The piles are to be truly driven in their respective positions until they do not move more than 3 inches with six blows from a 20-cwt. monkey falling 8 feet. They are to be shod with shoes weighing 15 lbs. each, and the heads securely hooped. Any pile that may be shaken in driving is to be drawn and replaced at the contractor's expense.

A variation of 5 per cent. in the size of piles or walings either way will be allowed from the specified sizes in the case of timbers that are more than 50 square inches in section.

The prices for the piling and carpenter's work must include all labours, waste, and nails, but all bolts, straps, washers, and large spikes over ¼ lb. in weight each, where ordered, will be paid for. The timbers are to be properly scarfed and sawn square or to the correct bevel, as the case may be, and all holes must be bored exactly at right angles or as directed by the engineer. The price for the timber must include the fixing of all bolts, straps, washers, and spikes.

48. **Concrete.**—The lime concrete shall consist of one part of ground Blue Lias lime to five parts of ballast. The materials having been measured are to be turned over three times, once dry and twice wet, and thrown from a height of 6 feet. The concrete is to be brought up in layers of not more than a foot at a time.

The cement concrete shall consist of one part of cement to eight parts of ballast, and be mixed in the same way as the lime concrete; but when it is deposited under water, it shall be lowered in boxes to the bottom, and every other possible means taken to prevent the cement from being washed out of the ballast.

No concreting shall be carried out in frosty weather. The surface of the concrete shall be finished to the proper levels, and slopes to receive the brickwork or whatever else is to be put on it. In the case of concrete abutments, retaining walls, and the like, the boarding is to be planed and so placed as to give a smooth face when it is removed, and the front 3 inches is to be formed of one part of cement to three of sand. Where concrete is used in walls, it shall be levelled up every foot throughout the length.

49. **Mortar.**—The materials for the mortar are to be carefully gauged and well ground in a mortar mill. One part of the slacked lime, or cement, as the case may be, shall be mixed with three parts by measure of sand, and used fresh. No mortar will be allowed to be beaten up again.

50. **Brickwork.**—The bricks, except when it is otherwise stated or directed, shall be laid in Old English bond in a thoroughly workmanlike manner, and no joint shall exceed ⅜ inch in thickness. Every course shall be thoroughly flushed up with mortar, and all bricks shall be bedded in mortar and be well wetted before they are used, plenty of water being also used in the work itself. The work is to be constructed in the most substantial manner, and

so as to give a neat and workmanlike appearance on the face. The heading joints must be truly vertical over each other and the horizontal joints perfectly straight and regular, and all cutting shall be neatly done. The arches are to be turned in half-brick rings with bond courses every 5 feet right through the arch. No batts shall be used except where absolutely necessary. All joints are to be neatly struck and drawn, and great care must be taken to keep the brick rings in the arches in true curves. No bricks are to be laid in frosty weather, and when the work is liable to be injured by the frost, the joints are to be raked out and pointed afterwards, and all work newly executed is to be covered over at night. For circular work of less than 3-feet radius, specially moulded bricks are to be used to suit the radius.

51. **Masonry.**—The coursed rubble masonry shall consist of square-faced stones laid in horizontal layers, averaging 8 inches in thickness and not less than 6 inches. The face stones shall average 8 inches in thickness, 12 in length, and 12 in depth, and no stone shall be used in the work unless it is longer in length and also in depth than it is in thickness. The backing shall be levelled up each course and all interstices well flushed up with mortar. No joint shall exceed $\frac{3}{8}$ inch in thickness. The face stones must be well bonded into the backing with bonders reaching 2 feet into the wall, and forming one-fourth of the whole face. The vertical edges to a depth of 3 inches and the beds of the stones are to be neatly dressed, but the face may be left rough or rock-faced if it does not project more than 3 inches beyond the neat line. All quoins are to be drafted with a 1-inch chisel. A distance equal to at least half the thickness of the stones shall intervene between the heading joints of each course.

In uncoursed rubble the work need not be laid in courses, and in random rubble the beds and joints need not be horizontal or vertical, but in other respects the work shall be executed in the same way as in the case of the coursed rubble masonry.

With ashlar masonry the stones in the backing shall be squared as well as those in the face, and the length and breadth of each stone must in each case be at least double its thickness. All ashlar shall be set in cement mortar. The exposed face of the stones may be left rough or rock-faced, provided that the edges are drafted all round 1 inch wide and the projection in front of the neat line does not exceed 3 inches. All skew-backs and arch-quoins must be truly worked to the lines laid down on the centres.

In other respects ashlar masonry shall be executed in the same way as rubble masonry. The prices given in the schedule are to include all labour, waste dowels, cramps, lead, sulphur, hoisting, setting, and every contingent expense.

52. **Centring.**—The centring is to be well and substantially constructed, and every lagging is to be gauged to a uniform thickness, and the upper surface wrought to the true curvature of the arch.

The centres shall rest on blocks which will admit of their being slacked gradually, and they shall not be so slacked or removed from any arch without the sanction of the engineer. Unless the engineer's representative gives instructions to the contrary, the centres shall be slacked ¼ inch, measured in a vertical direction, directly the whole arch is keyed, ½ inch a few days after, and a further ½ inch before they are removed altogether. Before the third slacking the spandrils shall be filled in, and the arch shall be completely backed up before the centres are removed.

In the case of bridges under banks and of viaducts, the centres shall remain in until the bank is tipped well beyond the bridge, or until sufficient arches have been turned to make the particular arch safe, as the case may be.

Every course of brick or stonework in the soffit is to be gauged and marked over the whole length of the centres before the arch is commenced.

All arches shall be left of the exact form shown upon the respective drawings, and should any change occur in the form of the arch from a defect in the centring or the supports thereof, the arch will have to be taken down and rebuilt upon stronger centring and supports at the expense of the contractor.

No parapets shall be built until the centres have been slacked and the arch left clear all round for 24 hours.

The cost of the centring is to be included in the price of the brickwork or stonework.

53. **Clay Puddle.**—The clay for puddle must be free from sand, grit, and other foreign matters. It shall be broken into small cakes and thoroughly tempered and punned, and kept moist until covered over.

54. **Pitching.**—The setts shall be of granite 5 inches deep, and not more than 4 inches wide. They shall be laid on a bed of sand 1 inch thick over a 6-inch bed of concrete, and shall be grouted with lias-lime mortar.

55. **Road Metalling.**—The bottom metal shall consist of large flat angular stones of not less than 12 inches area on plan. It shall be rolled with a 10-ton steam-roller until properly consolidated before the top metal is put on, and all holes shall be filled up.

The top metal shall be of tough angular stone broken to pass a 2½-inch ring, and shall be large enough to be retained by a ¾ inch ring. It shall be covered with sufficient water and binding material, and rolled till the surface is of the exact height and form shown on the sections or ordered by the engineer, and until the whole is properly consolidated into one solid mass.

Proper allowance must be made for consolidation in preparing the formation and supplying the stone, the thicknesses given in the drawings and quantities being the thicknesses that must be left after the rolling is finished.

56. **Asphalt.**—Wherever asphalt is shown on the drawings or is directed to be laid on, it is to consist of two coats, each ⅜ inch thick throughout. It shall be free from cracks and of a tough and pliable nature, and make a perfectly watertight covering. Either "natural" rock asphalt or a mixture of pitch, sand, and tar in approved proportions, and called herein "artificial" asphalt, is to be used as directed.

57. **Ironwork.**—The whole of the iron used shall be of British manufacture, and obtained from manufacturers approved of by the engineer. It shall be of the best description of boiler plate, free from blisters, scale, and all other defects, and also of such a quality as to be capable of sustaining a tensile stress of 21 tons per square inch of section when tested in the direction of the fibre of the iron, and of 17 tons when tested across the fibre, and shall show an elongation in 6¼ inches of not less than 10 per cent. in the direction of the fibre, and of not less than 3 per cent. across the fibre before breaking.

The ⅜-inch plates shall be capable of being bent cold to an angle of 45°, the ½-inch plates to an angle of 30°, and the ⅞-inch plates to an angle of 20°, and so on for the other thicknesses in like proportion, round a radius equal to the thickness of the plate.

All steel shall be manufactured by the Bessemer or Siemens-Martin process, and be sound and homogeneous, free from flaws, blisters, and other defects, and must be made straight and true by pressure and not by blows. It shall sustain a stress of not less than 28 and not more than 32 tons per square inch before breaking, and shall show an elongation of 20 per cent. in a length of 10 inches, and a contraction of area at the point of fracture of 45 per cent. It shall not contain more than 0·06 per cent. of phosphorus nor more than 0·06 per cent. of sulphur, and must be able to be bent double while cold round a radius equal to its own thickness without showing signs of fracture.

All rivets and bolts shall be of Low Moor iron, and shall be capable of sustaining a tensile stress of 25 tons per square inch of section, and shall show an elongation of not less than 20 per cent. in 6¼ inches before breaking.

All the edges and ends of the plates are to be truly and squarely planed. All holes shall be drilled, and be perfectly true and fair before the rivets are put in them, all the plates, bars, and angle, T- and channel-irons being put together and firmly held in correct position before the drilling is begun. The rivets shall be thoroughly heated and set up throughout their entire length. The fibre of the iron shall in all cases run in the direction of the greatest strain.

All castings are to be made from an approved mixture of tough grey pigs run from the cupola, and shall be perfectly free from flaws, scoriæ, sand-holes, air-bubbles, cold shutes, dirt, and other defects. The upper surfaces, as well as the beds of all bearing plates, are to be truly planed, and all rollers and pivots are to be truly turned. All pipes and cylindrical columns are to be circular in section and straight in length, both inside and out, as well as regular in thickness. The spigot ends of all pipes must enter the socket ends of all others without any cutting, chipping, or filing being necessary, but not more than ⅜ inch must be allowed for the lead joint. The iron shall be of such a quality as will admit of its being tapped, and sample bars 1 inch square shall sustain a weight of 7 tons per square inch if they are run at random from the cupola.

Wrought iron shall weigh at the rate of 40 lbs. per square foot of metal 1 inch thick, cast iron 3 per cent. less than this, and steel 3 per cent. more. All measurements and weights shall be calculated on this basis, and 5 per cent. on the weight of the plates and bars shall be allowed for rivets and bolts in lieu of the actual weight. In the case of angle-irons, tees, etc., an allowance equal to half their thickness shall be added to allow for the increased quantity of iron in the angles; thus a 3-inch × 3-inch × ½-inch L will be taken as weighing $\frac{5\frac{3}{4} \times 20}{12}$ lbs. per lineal foot. A variation of 2 per cent. from the thicknesses shown on the drawings will be allowed.

58. **Painting.**—The whole of the ironwork shall receive a coat of hot boiled oil before it is put together for riveting, and after it has been inspected and erected, three coats of paint laid on and of the colour as directed by the engineer. Before painting, the iron shall be scraped clean from all rust and scale. All timber shall be properly stopped and knotted before painting. Where tarring is ordered, Stockholm tar shall be used and laid on hot in two coats. All gas and water-pipes are to be coated with Dr. Angus Smith's solution while hot.

The price of ironwork is to include the cost of painting or coating, as the case may be.

59. **Drain-pipes.**—The thickness of all drain-pipes shall be one-twelfth of their diameter plus ¼ inch. They shall be perfectly straight and circular in section, both inside and out, and be properly salt glazed and of the best quality, and free from cracks and flaws. They shall be laid in perfectly straight lines, and where cement joints are specified, two turns of yarn shall be forced home with a proper tool into the collar, which shall then be thoroughly filled with cement mortar, and a cement fillet shall be formed right round to ensure a perfectly watertight joint. All junctions shall be on the skew, and care must be taken to remove everything that can obstruct the flow of the sewage from the inside of the pipes. The trenches shall be so excavated as to give the pipes an even bearing throughout, and when replaced, the excavated material shall be carefully punned.

60. **Permanent-way Materials.**—The steel for rails shall be sound, homogeneous, and free from blisters, flaws, and other defects, and sustain a stress of not less than 38 tons per square inch before breaking, and show an elongation of not less than 10 per cent. in a length of 2 inches. It shall contain from 0·35 to 0·45 per cent. of carbon, 0·70 to 1·00 per cent. of manganese, and not more than 0·15 per cent. of silicon, 0·08 of phosphorus, and 0·08 of sulphur. One per cent. of the rails will be placed on bearings 3 feet 6 inches apart, and subjected to a blow from a weight of 10 cwt. (20 in the case of the 70 and 84-lb. rails), and the whole consignment will be rejected if the rails that are tested show signs of failure under the following drops, the radius both of the bearings and of the falling weight being 5 inches:—

If the weight is 28 lbs. per lineal yard, as in Fig. 35, 5 feet
„ „ 42 „ „ „ 34, 15 „
„ „ 56 „ „ „ 33, 20 „
„ „ 70 „ „ „ 32, 15 „
„ „ 84 „ „ „ 31, 20 „

Rails over 60 lbs. per yard in weight shall be delivered in 30-foot lengths, and those under in 24-foot lengths; but 10 per cent. of the former may be in not less than 24-foot lengths, and 10 per cent. of the latter in not less than 20-foot lengths. The ends shall be sawn square, and four oval holes, as shown in the drawings, must be drilled in each. The rails shall be made by the Bessemer or Siemens-Martin process to the exact section shown, but a variation of $\frac{1}{4}$ inch from even feet will be allowed in the lengths and of 1 per cent. in the weight. A certain proportion of rails 3 inches shorter than the standard length are to be supplied. The fish-plates shall be of the steel as specified for girders, and be of the section and drilled as shown.

All bolts shall be of Low Moor iron as specified, but spikes and dogs may be of Staff-iron, provided they satisfy the tests specified for iron plates.

The chairs shall be of the same quality as the castings, as specified in the ironwork clause, and shall be made to exactly fit the rail and key.

The sleepers shall be creosoted as specified under the head of timber. They shall be 8 feet 11 inches in length, and if first class, at least 10 inches × 5 inches in section, with not more than $1\frac{1}{2}$-inch wane on the two outside corners; if second class, they shall be at least 9 inches × $4\frac{1}{2}$ inches, half-round in section. In both cases the wood shall be well seasoned and of good quality, and free from splits and dead knots.

The keys shall be of compressed fir of the exact size shown in the section.

61. **Fencing.**—The contractor is to provide, at his own expense, all temporary gates and fencing which may be required by the owners of adjacent property, or which may be considered by the engineer to be necessary.

The close-boarded and pale and space-fences are to consist of oak posts, and larch, Memel, or pitch-pine rails and boards, or pales. The whole to be wrought and painted (three coats).

The post and rail fencing is to be of fir, sawn and creosoted.

The posts, rails, and stays are to be not less than 7 inches × 3 inches, 3½ inches × 1½ inches, and 3½ inches × 2½ inches respectively at the smallest part. The rails are to be 18 feet in length, and attached to the posts and stays by 4-inch wrought-iron nails properly clenched. The top of each post is to be secured from splitting by having a piece of new hoop-iron, 1¼ inches wide and 16 B.W.G., nailed round it.

The iron fencing is to be of wrought iron throughout, except where it is specially noted on the drawings that it is to be cast. The posts are in every case to be firmly fixed in the ground and well rammed.

The ditches are to be constructed as shown on the drawing, and puddled where necessary. The soil from them is to be formed into a mound in which to set the quicks as shown, but where the material removed from the ditch is of not good enough quality, it must be removed, and good soil brought to take its place in the mound. Before the quicks are set the ground is to be trenched two spits deep. It is to be weeded, and the surface twice dug during the term of maintenance. The quicks are to be set eight to the yard in two rows 9 inches apart; they are to be three years old, two years transplanted, and set between the 1st day of October and the 1st day of March. Where the material excavated from the side ditch is at all rocky or chalky, or otherwise appears to the engineer to be of an unsuitable nature for the quicks to grow in, the material on the site of the bank shall be removed, and good earth or soil brought to replace it to a depth of a foot.

62. **Earthworks.**—The cuttings are to be excavated and the banks formed to the lines and levels shown on the section and cross-sections. When finished and soiled, they shall at every point be of the full widths, and the slopes shall be of the inclinations given. Proper allowance for shrinkage in the widths and levels shall be made in forming the embankments, and all deficiencies made good at the contractor's expense. The side tips shall be kept in advance of the middle tips. When an embankment rests on sloping ground, the same shall be benched in such a manner as may be directed, the excavation for the benchings being paid for at the same rate as that in the nearest cutting. The embankments must be formed of the full width at once, and not widened by material tipped or cast down the sides. No tip shall exceed 25 feet in height; where the banks are higher they

shall be tipped in two lifts, and the price given in the schedule for excavation must include the cost of this.

The sides of all cuttings and embankments, as they become consolidated, must be properly trimmed to their respective slopes, and then sodded or covered with a layer of soil 4 inches thick, which, at the proper season, shall be sown with rye grass and white clover-seed in equal proportions (30 lbs. per acre), repeated in case of failure until a good turf is formed.

The price given for the soiling must include the supplying of the soil and filling up the places it is taken from.

So much of the clay as may be required by the engineer shall be well burnt before it is tipped into the embankments. All peat and spongy matter that may be on the site of the embankments shall be excavated at the schedule price for excavation. No slurry, snow, mud, or other soft or unfit material is to be tipped into the embankment, and all such must be removed from the bank which is being constructed before the tipping is continued. Proper drains must be constructed at the contractor's expense to remove all the water which falls both in the cuttings and on the banks, and to keep the surfaces of both perfectly dry. All banks shall be trimmed and soiled as soon as possible after they have been tipped, and in no case more than three months after each portion has been excavated or tipped, and where the earth on being tipped does not form the specified slope, it shall at once be brought to such slope.

Where directed, drains shall be cut in the slopes and filled up with large stone or slag, and a 12-inch thickness of stone shall be placed behind all walls to prevent the accumulation of water.

The foundations shall be excavated to the depths and widths shown, or to such extra depths and widths as may be directed, and all loose and dirty material and water shall be removed before the concrete is put in.

Great care must be taken to thoroughly back up all bridges and prevent unequal loading. For this purpose the contractor must provide all necessary temporary timber staging, etc., at his own expense, and must at his own expense rebuild any works that may be injured.

The prices given for excavation, whether in the cuttings or foundations, must cover the cost of removing all timber, roots, hedges, trees, walls, and all other matters which may be below the surface or on the site, and the trimming of the slopes.

The dry-earth backing to bridges and other works shall be thoroughly rammed in 6-inch layers as the brickwork proceeds.

63. **Ballasting and Laying the Permanent Way.**—The greatest care must be taken in laying out the line in accordance with the curves and straight lines shown on the plans, and in accordance with the levels and gradients shown on the sections. Should any cutting be excavated to too great a depth, or should any embankment be too low from whatever cause, the contractor shall supply sufficient ballast to make up the defect at his own expense, and he will not be allowed to do this with any other materials.

The ballast shall consist of large rough stone or slag up to 9 inches below rail-level, and the remainder of broken stone, clean sharp gravel, ashes or slag chippings, all of which must pass through a screen of 36 meshes to the square foot and be retained by one of 576 meshes. The bottom ballast shall be spread before the permanent way is laid down. The sleepers are to be planed in a machine to give the rail the proper inclination, and the spike or bolt-holes are to be bored right through them.

On straight lines the rails are to be level; on curves such super-elevation shall be given to the outer rail as may be directed. The joints are to be perfectly true and opposite to each other, a space of $\frac{3}{16}$ inch in hot and $\frac{5}{16}$ inch in cold weather being left between the rails at each to allow for expansion.

No greater lift than 4 inches shall at any time be given. All sleepers are to be uniformly packed and kept so, and no horses are to be allowed to work on the permanent way, which may only be used by the contractor for the purpose of carrying ballast and other materials in trucks of proper construction, and not in tip-waggons.

No joint in the rails or timbers shall be over any part of a bridge, except where it is unavoidable, but the rails or timbers shall be cut if necessary, and no closure must be less than 12 feet in length.

64. **Maintenance of Way.**—The contractor shall provide two men for every mile of single line for the whole period during which he has to maintain the works. These shall be arranged in gangs of such numbers as the engineer shall direct, and one in each gang shall act as foreman over the rest. The contractor shall provide all necessary flags, signal lamps, fog signals, trolleys, and all other appliances for maintaining the railway and securing

the safety of the trains. The men shall work at least 56 hours each in the week, and as much longer as fog, accident, or other cause may render necessary. The foremen shall take their instructions from the engineer, and work in accordance with the company's rules, a copy of which will be given them.

65. **Water-pipes.**—All pipes shall be so laid as to give a covering of 2 feet 6 inches of earth or road metal over their barrels. After the spigot end has been pushed home into the socket of the next pipe and all dirt has been removed, two complete laps of white hempen yarn shall be forced into the end of the socket with a proper tool, and the remainder of the joint shall be filled in with soft blue lead, which shall be properly set up by caulking-irons when cold. The trenches shall be refilled in 6-inch layers and properly rammed.

66. **Tunnelling.**—The tunnels shall be constructed according to the sections shown or to such other sections as may from time to time be ordered. The ground shall be carefully got out and close poled and timbered with timbers of sufficient size, proper allowance being made for subsidence. Where the ground is very treacherous the timber shall be left in, but no allowance shall be made to the contractor in payment for this. The spaces between the brickwork, as shown on the drawings, and the ground shall be filled in solid with brickwork. Where there is much water the brickwork shall be set in cement, and every possible precaution taken to prevent the cement being washed out. In tunnelling under buildings or through bad material, the ground shall not be got out more than 6 feet in advance of the completed work, and in no case more than 15 feet. The centres shall not be slacked till the length next in advance shall have been completed ready for the arch. They shall be constructed in accordance with the drawings, or in such other manner as may be approved by the engineer.

The timbering and work generally shall be done in such a manner as the engineer approves, with bars, cills, rakers, props, struts, and poling boards of a size which is in his opinion sufficient; but the contractor shall, in spite of the engineer's approval, repair and make good any failures that may occur, and take out any extra ground which may be necessary owing to the crown-bars sinking or the sides coming in more than he has allowed for.

He shall also take down and rebuild any brickwork which is more than 1 inch out of line or level according to the straight lines, curves, and gradients shown on the plans and sections.

No bottom heading shall be driven, and the ground shall not be exposed longer than is absolutely necessary, and any extra work that the engineer may deem necessary owing to the ground being left open too long, shall be done at the contractor's own cost.

## BILL OF QUANTITIES.

### PRELIMINARY ITEMS.

| No. of clause. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| 1 | Provide water, lights, firing, and plant of every kind | | | | |
| 3 | Do. for testing materials and appliances for the same | | | | |
| 5 | Do. do. the best materials and workmanship | | | | |
| 8 | Do. do. all charges in connection with all accidents to persons and property, and compensation to workmen, fire, and accident insurance | | | | |
| 8 | Do. do. timbering, watching, etc., required by the engineer | | | | |
| 8 | Do. repairing all defects | | | | |
| 9 | Do. notices and fees to local and other authorities, and protecting and maintaining all roads, etc., interfered with | | | | |
| 9 | Do. all temporary crossings and diversions | | | | |
| 11 | Do. magazines and proper cases for explosives and licences | | | | |
| 12 | Do. a competent foreman | | | | |
| 13 | Do. an office on the works | | | | |
| 14 | Do. extra police and prevention of disease | | | | |
| 19 | Do. setting out the works and correcting errors | | | | |
| 20 | Do. copies of drawings | | | | |
| 21 | Do. monthly payments, less 10 per cent. | | | | |
| 23 | Do. nett measurements and all extra labours in circular facework, etc., and all pointing and cuttings | | | | |
| 28 | Do. commencing within a month and completion within 12 months, or paying damages at £10 per day | | | | |
| | Carried forward | | | | |

PRELIMINARY ITEMS—*continued.*

| No. of clause. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| | Brought forward | | | | |
| 30 | Provide for land for temporary purposes and allow for delay in obtaining land | | | | |
| 31 | Do. do. interference with work by other contractors and persons | | | | |
| 33 | Do. clearing the site of all buildings, trees, hedges, etc. | | | | |
| 33 | Do. sand, stone, and ballast that may be used free of charge if found on the site | | | | |
| 34 | Do. clearing up on completion | | | | |
| 35 | Do. 6 months' maintenance | | | | |
| | (NOTE.—This does not include the men required for packing the line or their tools, but does include all ballast and other materials.) | | | | |
| 37 | Provide for all incidental works and contingencies | | | | |
| 38 | Do. the carriage of all men and materials | | | | |
| 38 | Do. watching, temporary works, repairs of roads, etc. | | | | |
| | Do. carrying out the work in strict conformity with the specification | | | | |
| 42 | Do. do. clean, sharp furnace ashes or sand, and washing if necessary | | | | |
| 42 | Do. do. ballast broken to pass a 2½-inch ring | | | | |
| 43 | Do. freshly burnt blue lias lime | | | | |
| 43 | Do. Medway cement, cement store, and cooling and testing | | | | |
| 44 | Do. square, hard, well-burnt bricks for backing | | | | |
| 44 | Do. do. uniform colour for facework | | | | |
| 44 | Do. do. brindled for facework | | | | |
| 45 | Do. Blue Pennant, York, or Derbyshire stone for caps and bedstones | | | | |
| 46 | Do. seasoned undefective Memel or pitch-pine timber | | | | |
| | Carried forward | | | | |

PRELIMINARY ITEMS—*continued.*

| No. of clause. | | @ | £ | *s.* | *d.* |
|---|---|---|---|---|---|
| | Brought forward . . | | | | |
| 46 | Provide or 8 lbs. of creosote in Memel, 4 lbs. in pitch-pine . . . . . . . . . . | | | | |
| 46 | Do. tarring with Stockholm tar . . . . . | | | | |
| 46 | Do. English oak . . . . . . . . . . . | | | | |
| 48 | Do. 1 of lime to 5 of ballast, measured dry . | | | | |
| 48 | Do. 1 of cement to 8 of ballast, measured dry, turning over once dry and twice wet in each case . . . . . . . . . . . | | | | |
| 48 | Do. 3 inches of 1 of cement to 3 of sand for facing walls . . . . . . . . . . . | | | | |
| 49 | Do. 1 of lime to 3 of sand for lime mortar . . . . . . . . . . . . . | | | | |
| 49 | Do. 1 of cement to 3 of sand for cement mortar . . . . . . . . . . . . . | | | | |
| 50 | Do. $\frac{3}{8}$-inch mortar joints, all cuttings and pointing . . . . . . . . . . . . | | | | |
| 52 | Do. centring in brickwork price . . . . | | | | |
| 54 | Do. granite setts, $\frac{2}{9}$ ton per square yard and 1 inch of sand, and grouting with lime mortar . . . . . . . . . . . . . | | | | |
| 55 | Do. forming, laying bottom metal, rolling, laying top metal, rolling and supplying water and binding material . . . . . | | | | |
| 57 | Do. supply, haulage, erection, and scaffolding for girder work . . . . . . . . . . | | | | |
| 59 | Do. pipes, yarn, cement, excavation, laying, and evenly bedding, and refilling and ramming . . . . . . . . . . . . | | | | |
| 60 | Do. supplying, hauling, and unloading permanent-way materials . . . . . . | | | | |
| | (NOTE.—No prices are to be attached to the above items, but provision for them must be made in the prices following in this schedule.) | | | | |
| 31 | Hauling and unloading materials 100 tons | | | | |
| | Carried forward . . | | | | |

FENCING.

| yards. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | Brought forward . . | | | | |
| 1000 | Lin. | Creosoted post and five-rail fence, including all materials and labour . | | | | |
| 200 | „ | Arris rail fencing to approaches, including painting, and fixing . | | | | |
| 100 | „ | Pale and space fencing, do. . . . | | | | |
| 1000 | „ | Excavating ditch 2 feet deep and forming mound . . . . . . | | | | |
| 1000 | „ | Planting hedge with quicks, 9 inches each way, and restoring any that may die within 12 months of planting . . . . . . . . | | | | |
| 30 | „ | Grubbing hedge outside line of excavation . . . . . . . . | | | | |
| | No. 20 | Field gates, 10 feet clear between posts, including two 8-inch × 8-inch oak posts, each 7 feet long, with ironwork and fastenings to each . . . . . . . . . . | | | | |
| | No. 12 | Gradient posts, including painting, lettering, and fixing . . . . | | | | |
| | „ 12 | Mile and quarter posts, do. . . . | | | | |

EARTHWORK.

| | | | | | | |
|---|---|---|---|---|---|---|
| 20,000 | Cube | Excavation in cutting and running to embankment and trimming slopes . . . . . . . . . . | | | | |
| 200 | „ | Extra price for road and stream diversions and ponds . . . . | | | | |
| 500 | „ | Excavation in benchings . . . . | | | | |
| 1000 | „ | Excavating drains in slopes of cuttings and banks, not more than 4 feet deep, and finding stone and filling up with the same . . . | | | | |
| 1000 | „ | Do. not more than 10 feet deep . | | | | |
| | | Carried forward . . | | | | |

EARTHWORK—*continued.*

| yards. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | Brought forward . . | | | | |
| 1000 | Cube | Wheeling clay, burning same, and finding coal, and wheeling back into position; not more than 5 chains wheeling in all . . . | | | | |
| 100 | „ | Extra price for raised approaches, measured in bank . . . . . | | | | |
| 2000 | Sup. | Stripping or supplying soil, storing same, and spreading 4 inches thick on slopes, and sowing 30 lbs. of grass seed per acre . | | | | |
| 1000 | „ | Forming surface for ballasting . . | | | | |

BRIDGES AND WALLS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 200 | Cube | Excavation to foundations, including pumping and timbering and removing surplus; not more than 6 feet deep . . . . | | | | |
| 100 | „ | Do. more than 6 feet deep . . . | | | | |
| 20 | Lin. | Cofferdam, including cutting off piles below bed of river . . . | | | | |
| 100 | Cube | Concrete in cement in foundations . . . . . . . . . . | | | | |
| 50 | „ | Do. on iron flooring . . . . . | | | | |
| 50 | „ | Do. in spandrils . . . . . . . . | | | | |
| 40 | „ | Lime concrete . . . . . . . . | | | | |
| 200 | „ | Brickwork in lime in abutments, piers, wings, etc.. . . . . . . | | | | |
| 20 | „ | Do. in parapets . . . . . . . | | | | |
| 50 | „ | Do. arches, including centring . . | | | | |
| 100 | „ | Extra price for cement . . . . | | | | |
| 20 | „ | Do. do. blue brickwork . . . . | | | | |
| 20 | „ | Do. do. brindled brickwork . . . | | | | |
| | | Carried forward . . | | | | |

BRIDGES AND WALLS—*continued.*

| yards. | feet. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| | | | Brought forward . . | | | | |
| — | 20 | Cube | Ashlar in caps and girder-beds . | | | | |
| 50 | — | „ | Dry stone lining behind walls . | | | | |
| 200 | — | „ | Do. earth rammed behind walls and over footings . . . . . | | | | |
| 20 | — | „ | Clay puddle and depositing in position . . . . . . . . | | | | |
| — | 30 | Lin. | 9 × 4½ B. brick, bull-nosed angles | | | | |
| — | 30 | „ | 4½ × 3 do., plinth . . . . . | | | | |
| — | 60 | „ | 18 × 6 do., bull-nosed coping checkered on top . . . . . | | | | |
| — | 20 | „ | 14 × 6 do. do. . . . . . . | | | | |
| 50 | — | Cube | Rubble masonry . . . . . . | | | | |
| 100 | — | „ | Do. coursed . . . . . . . | | | | |
| 50 | — | „ | Random rubble . . . . . . | | | | |
| 100 | — | Sup. | Natural asphalt, ¾ inch thick . | | | | |
| 100 | — | „ | Artificial do. of pitch, and tar | | | | |
| — | 80 | Cube | Memel or pitch-pine in piles, including driving and staging and all labour . . . . . . | | | | |
| — | 30 | „ | Do. in walings, plates, and joists, do. . . . . . . . . . . | | | | |
| — | 40 | „ | Do. flooring, do. . . . . . . | | | | |
| — | 10 | „ | Do. wrot. all round, framed and braced, do. . . . . . . . | | | | |
| — | 10 | „ | Oak, do. do. . . . . . . . | | | | |
| 100 | | Sup. | Painting 4 coats on wood or iron | | | | |
| tons. | cwts. | qrs. | lbs. | | | | |
| 30 | 3 | 2 | 7 | Steel in plate girders, including painting . . . . . . . . | | | |
| 20 | 14 | 1 | 14 | Do. lattice girders, do. . . . . | | | |
| 7 | — | — | — | Do. truss do. do. . . . . . . | | | |
| 1 | — | — | — | W.I. in bolts, nuts, straps, shoes, etc., do. . . . . . . . . . | | | |
| 1 | — | — | — | C.I. in bedplates, including planing and fitting, do. . . . | | | |
| 5 | — | — | — | Do. in columns, do. . . . . . | | | |
| | | | | Carried forward . . | | | |

### PERMANENT WAY.

| tons. | cwts. | qrs. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| | | | Brought forward . . | | | | |
| 200 | 10 | 3 | Providing rails at nearest station | | | | |
| 21 | 3 | — | Do. fish-plates and bolts do. . . | | | | |
| 5 | — | — | Do. spikes do.. . . . . . . | | | | |
| 100 | — | — | Do. C.I. chairs do. . . . . . | | | | |
| | No. 2000 | | Do. sleepers do. . . . . . . | | | | |
| 452 | | | Unloading, carting, and delivering materials . . . . . . | | | | |
| yards. | | | | | | | |
| 2000 | Lin. | | Laying permanent way (single line of 2 rails), including straightening, lifting, drilling, etc. . . . . . . . . . | | | | |
| 100 | „ | | Extra for junction work (measured from point of switches to just beyond crossing) . . . . . | | | | |
| 100 | „ | | Slewing single line, including opening out, lifting, cutting, packing, and boxing up . . . | | | | |
| | No. 3 pr. | | Providing switches . . . . . | | | | |
| | „ 3 | | Do. crossings with two guards each | | | | |
| | „ 1 pr. | | Do. elbows do. . . . . . . | | | | |
| | „ 3 „ | | Laying switches . . . . . . | | | | |
| | „ 1 „ | | Taking out do. . . . . . . | | | | |
| | „ 5 | | Laying crossings or elbows . . | | | | |
| | „ 1 | | Taking out do. . . . . . . | | | | |
| | „ 2 | | Providing and fixing buffer-stops . . . . . . . . . | | | | |
| | „ 3 | | Do. do. point levers . . . . . | | | | |
| 2000 | Cube | | Do. and laying ballast below bottom of sleeper . . . . . | | | | |
| 1000 | „ | | Do. do. above . . . . . . . | | | | |
| | | | Do. 5 men for 56 hours a week each as a minimum for 6 months, with all tools for lifting and packing . . . . | | | | |
| | | | Carried forward . . | | | | |

### ROADS.

| yards. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | Brought forward . . | | | | |
| 100 | Sup. | Providing and laying hard core 6 inches thick after rolling . | | | | |
| 50 | „ | Do. top metal of broken stone 3 inches thick after rolling, and including binding . . . . | | | | |
| 50 | „ | Do. of granite do. . . . . . | | | | |
| 100 | „ | Rolling bottom metal . . . . | | | | |
| 100 | „ | Do. top do., and finding water, and marl, and forming to proper surface . . . . . . | | | | |
| 50 | „ | Providing and laying hard core 3 inches thick after hand-rolling to footpaths, including rolling | | | | |
| 50 | „ | Do. asphalt paving 3 inches thick in 2 coats and hand-rolling . . . . . . . . | | | | |
| 100 | Lin. | Do. and setting 10-inch × 6-inch granite kerb, 12-inch × 4-inch scoriæ channel, and 3-inch × 5-inch setts, all on 3 inches of concrete . . . . . . . . | | | | |
| | No. 3 | Do. C.I. grates and glazed gulleys, 18 inches diameter, 3 feet deep, and connecting to drain. . . | | | | |
| 20 | Sup. | Granite pitching, 5 inches deep, laid on 6 inches of concrete, including concrete . . . . | | | | |

### DRAINAGE.

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 | Lin. | 6-inch best quality glazed stoneware, socketed drain-pipes with open joints, including excavation, refilling, and ramming; invert not more than 4 feet, and averaging 3 feet below surface | | | | |
| 100 | „ | 9-inch do. with clay joints and do. | | | | |
| | | Carried forward . . | | | | |

DRAINAGE—*continued.*

| yards. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | Brought forward . . | | | | |
| 100 | Lin. | 9-inch best quality glazed stoneware, socketed drain-pipes, with yarn and cement joints, including excavation, refilling, and ramming, invert not more than 6 feet, and averaging 4 feet below the surface . . | | | | |
| 100 | " | 12-inch do., Hassell's patent joints, and do. . . . . . . | | | | |
| 100 | Cube | 8 to 1 lime concrete, 3 inches beyond pipes each way, either over or under pipes . . . . | | | | |
| 5 | Lin. | 12-inch channel-pipes to manhole inverts . . . . . . . | | | | |
| | No. 20 | 9 × 6 junctions extra on price of 9-inch pipe . . . . . . . | | | | |
| | " 20 | 6-inch stoppers set in clay . . | | | | |
| | " 20 | Do. bends . . . . . . . . | | | | |
| | " 3 | C.I. manhole covers, 20-inch opening, No. 2001 in — list, with galvanized iron dirt-boxes, including setting . . . . . | | | | |
| | " 1 | C.I. lamphole cover, 9-inch opening, do.. . . . . . . . | | | | |
| | " 10 | Galvanized wrot. step-irons, 9 lbs. each, and setting . . . . . | | | | |
| | " 1 | Field's flushing syphon, size No. 3, for 9-inch drain, and setting . | | | | |
| 10 | Cube | Extra excavation for manholes, flushing tanks, and concrete under pipes, and removing surplus . . . . . . . . | | | | |
| 5 | Sup. | $\frac{7}{8}$-inch cement, rendering in 2 coats, the first $\frac{3}{4}$ inch thick, of 2 of sand to 1 of cement, and the second $\frac{1}{8}$ inch thick of neat cement . . . . . . . | | | | |
| | | Carried forward . . | | | | |

DRAINAGE—*continued.*

| yards. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | Brought forward . . | | | | |
| 20 | Lin. | 4-inch diam. C.I. ventilating pipe, including painting, bends, and fixing . . . . . . . . . | | | | |
| | No. 1 | Domicile wire cage to top of do. | | | | |
| | „ 1 | Mica flap fresh-air inlet-valve . | | | | |
| | „ 1 | Syphon-trap, No. — in — catalogue, and fixing . . . . . | | | | |
| | „ 1 | 6-inch yard-gulley, No. — in — catalogue do. . . . . . . | | | | |

WATER-PIPES.

| tons. | cwts. | qrs. | lbs. | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 2 | — | 3-inch C.I. pipes, coated with Dr. A. Smith's solution, and delivered on site . . . . . . | | | | |
| 10 | 7 | 1 | 7 | 6-inch do. do. . . . . . . . . | | | | |
| — | 15 | — | — | Specials do. . . . . . . . | | | | |
| — | 5 | — | — | Lead in joints do. . . . . . | | | | |

| yards. | | | | | | |
|---|---|---|---|---|---|---|
| 100 | Lin. | Excavating trench 3 feet in average depth, and not more than 5 feet, laying 3-inch pipes, including finding yarn and jointing, refilling and ramming and taking off, replacing and making good metalling . . . | | | | |
| | No. 2 | 3-inch Fullway valves, socket-ends, bronze faces, No. — in — list, and fixing, including brick pits and covers, No. — in — list, with 4-inch granite cubes 12 inches wide all round . . | | | | |
| | „ 2 | Ball hydrants do. do. . . . . | | | | |
| | | Tapping main under pressure and inserting ¾-inch ferrule and cover, including excavation . | | | | |
| | | Carried forward . . | | | | |

WATER-PIPES—*continued.*

| yards. | feet. | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| | | | Brought forward . . | | | | |
| 10 | — | Lin. | ¾-inch galvanized W.I. water-piping, laid in trench 2 feet 6 inches below surface, including excavation and refilling . | | | | |
| 10 | — | | ¾-inch do. gas-piping, tested for water, do. do. . . . . . . . | | | | |
| | | No. 1 | ½-inch screw-down valve, No. — in — list, including cover-pit and fixing . . . . . . . . | | | | |
| | | „ 1 | ¾-inch bend . . . . . . . . | | | | |
| | | „ 1 | ¾ × ½ reducing piece . . . . | | | | |
| — | 100 | Lin. | 5½-inch diameter, boring to 100 feet below surface . . . . | | | | |
| — | 100 | „ | Do. from 100 to 200 feet do. . . | | | | |
| — | 200 | „ | 5-inch diameter W.I. tubing, $\frac{3}{16}$ inch thick, lining to do. and fixing . . . . . . . . . . | | | | |
| | | No. 1 | Shoe and No. 1 cap to do. . . . | | | | |
| | | | The size given in the case of all pipes indicates the internal diameter . . . . | | | | |

DAY WORK.

| hours. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| 100 | Navvies . . . . . . . . . . . . . . | | | | |
| 50 | Labourers . . . . . . . . . . . . . | | | | |
| 50 | Bricklayers . . . . . . . . . . . . . | | | | |
| 20 | Masons . . . . . . . . . . . . . . | | | | |
| 20 | Carpenters . . . . . . . . . . . . . | | | | |
| 20 | Smiths . . . . . . . . . . . . . . | | | | |
| 10 | Platelayers . . . . . . . . . . . . . | | | | |
| 20 | Boys . . . . . . . . . . . . . . . | | | | |
| 100 | Driver, cart, and one horse. . . . . . . . | | | | |
| 50 | „ „ two horses . . . . . . | | | | |
| | Carried forward . . | | | | |

DAY WORK—*continued.*

| tons. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| | Brought forward . . | | | | |
| 1 | Lias lime on works (carting extra) . . . . | | | | |
| 1 | Cement „ „ „ „ . . . . | | | | |
| cubic feet. | | | | | |
| 20 | Timber left in foundations . . . . . . . | | | | |
| 10 | New timber under 12 inches by 12 inches . | | | | |
| 10 | „ „ over „ „ „ . | | | | |
| 10 | Creosoting extra . . . . . . . . . . | | | | |
| cwt. | | | | | |
| 1 | Nails, spikes, and bolts . . . . . . . . | | | | |
| No. | | | | | |
| 1000 | Bricks, common . . . . . . . . . . . | | | | |
| 1000 | „ blue. . . . . . . . . . . . . | | | | |
| 1000 | „ brindle. . . . . . . . . . . | | | | |
| 1000 | „ red . . . . . . . . . . . . . | | | | |
| | Amount of tender . . | | | | |

The amounts given in this bill of quantities are in no way guaranteed, but the work actually done will be measured and paid for at the rates filled in by the contractor.

### SCHEDULE OF DRAWINGS.

Drawing No. 1. General plan.
„ „ 2. Working section.
„ „ 3. Cross-sections (7 sheets).
„ „ 4. Sections of cuttings and embankments, showing rails, ballast, and drains.
„ „ 5. Fencing, level crossings, and catch-pits.
„ „ 6. Bridge at 3 miles 5·00 chains.
„ „ 7. „ „ 5 „ 1·30 „
„ „ 8. „ „ 8 „ 0·00 „
„ „ 9. „ „ „ „ „ „ (steelwork).
„ „ 10. Retaining wall at 6 miles 5·00 chains.
„ „ 11. Station yard „ 0 „ 0·00 „
„ „ 12. „ „ „ 5 „ 30·00 „
„ „ 13. „ „ „ 9 „ 10·00 „
„ „ 14. „ buildings.
„ „ 15. Platelayer's cottage.

# CHAPTER XIV.

## *MEASUREMENTS AND ESTIMATES.*

**Earthworks—Approximations—Fencing—Bridge work—Permanent way—Quantities in an arched bridge—Estimates—General charges—Fencing—Earthwork — Plant — Materials — Labour — Foundations — Pumping—Timbering—Concrete—Loss of bulk—Brickwork—Bricks and mortar—Masonry—Timber—Ironwork—Road metal.**

THE system of estimating and measuring up work usually adopted by engineers differs considerably from that employed by architects and quantity surveyors. It is not usual to go into the same detail and to allow for all labours extra, but one price is made as far as possible to include everything. For example, in the case of brickwork the price per cubic yard should cover facework, pointing, cuttings, arches, centring, and the like, but in the schedule of prices it should be clearly stated that it does this; indeed, everything should be made so clear that contractors in tendering may see at a glance exactly what they have to allow for.

**Earthworks.**—Earthwork is usually measured by the amount taken from the cuttings, and the price is made to include the running and tipping the stuff into the embankment, the trimming of the slopes of both cutting and bank and sometimes the cutting of benchings on side-long ground. Work in connection with such slips as are not caused by the carelessness of the contractor is paid for, such as excavating drains in the slopes, and filling them with stone, burning clay, dry stone walling, etc. An extra price is given for tipping raised approaches, and also for excavating sunk approaches, ponds, and stream diversions. Soiling is taken by the superficial yard, and grubbing hedges (outside the line of excavation), the drains outside the fences to cut off the land drains, the side ditches, quick-set fence, and the drains in the cutting by the lineal yard.

In taking out the quantities of earthworks, Bidder's tables are sometimes used, but it is better to work from cross-sections or to measure up on the ground. This last method works very well for shallow cuttings where the top width can be taken with a tape, and the depth by means of a levelling staff, the tape being used to indicate the surface of the ground. In both cases the quantity included is half a chain each side of the chain-point, but where the cutting is rapidly increasing in depth the amount given is rather too small. To take, as an extreme case, a chain where the depth is 20 feet at the chain-point, 10 feet 50 links from it in one direction, and 30 feet at 50 links in the other direction, the surface across being level, the slopes 1 to 1, and the formation width 17 feet, the content by this methods would be—

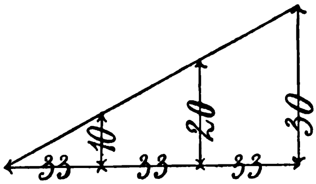

*FIG. 80.*

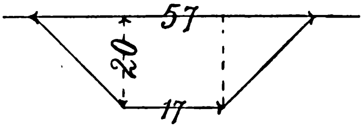

*FIG. 81.*

$$C = 66 \text{ feet} \times \frac{17 + 57}{2} \times 20 = 66 \times 740$$

but the true measurement is—

$$C' = 66 \times 17 \times 20 + 2\,\tfrac{99}{3} \,.\, \frac{30 \times 30}{2} - 2 \,.\, \tfrac{33}{3} . \frac{10 \times 10}{2}$$
$$= 66\{340 + 450 - 17\}$$
$$= 66 \times 773$$

*i.e.* a difference of nearly 5 per cent.

The error made in simply taking the area at the centre of a chain and multiplying by the length may be found for any heights in the following manner:—

Let $x$ be the depth at one end, and $x + a$ at the other.

The true contents of the two slopes at 1 to 1 will be—

$$C' = (x + a)^2 \frac{66 + 66\frac{x}{a}}{3} - x^2 \frac{66\frac{x}{a}}{3} = 66x^2 + 66ax + 22a^2$$

The approximate contents are—

$$C = \left(\frac{2x + a}{2}\right)^2 66 = 66x^2 + 66ax + \frac{33}{2} . a^2$$

So that the error in the approximation is—

$$\frac{11}{2}a^2 = \frac{11}{54}a^2 \text{ cubic yards}$$
$$= \frac{a^2}{5} \quad ,, \quad ,,$$

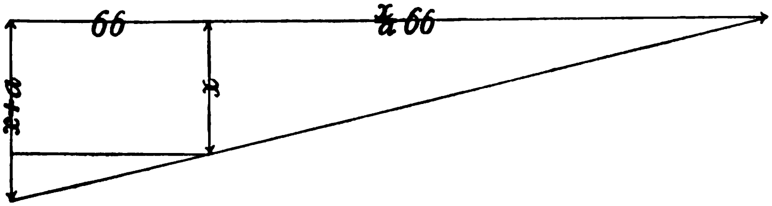

FIG. 82.

| | | | | |
|---|---|---|---|---|
| If therefore $a$ = | 1 | the error = | 0 | cubic yards |
| ,, ,, | 2 | ,, | 1 | ,, |
| ,, ,, | 3 | ,, | 2 | ,, |
| ,, ,, | 4 | ,, | 3 | ,, |
| ,, ,, | 5 | ,, | 5 | ,, |
| ,, ,, | 6 | ,, | 7 | ,, |
| ,, ,, | 7 | ,, | 10 | ,, |
| ,, ,, | 8 | ,, | 13 | ,, |
| ,, ,, | 9 | ,, | 16 | ,, |
| ,, ,, | 10 | ,, | 20 | ,, |

For 1½ to 1 slopes the error would be half as much again.

**Fencing.**—Fencing is taken by the lineal yard, and the price should include all nails, posts, post-holes, circular work, tarring, etc., and that for the gates all ironwork posts, painting, and fixing.

**Bridgework.**—The price for excavating foundations should include all pumping, timber, and timbering, but in some cases an allowance is made for cofferdams by the lineal foot, and timber, which is ordered to be left in, is paid for. The dry packing, which is placed behind all abutments and wing walls to lead the water which would otherwise accumulate there to the weep-holes, is measured by the cubic yard, as is also the dry material which is run behind the abutments, and punned to secure them, more especially while the bank is being tipped. This punned material is, under ordinary circumstances, made 4 feet thick at the top, and batters downwards at a slope of ½ to 1.

Concrete in foundations and over jack arches or flooring is measured by the cubic yard, and the price made to include all the boarding which may be necessary.

Brickwork is put under various heads according as it is in abutments, arches, jack arches, or parapets, etc. The small panels in parapets are not usually deducted. To properly take out the quantities of even the simplest bridge requires some knowledge of solid geometry. In making an approximation, errors of several yards are likely to occur, and these become important with high-priced work. Asphalt is measured by the super yard, ashlar by the cubic foot from the dimensions of the stone out of which the cap or other stone has to be cut, and coping, plinths, bull-nosed quoins, etc., by the lineal foot. Ironwork is taken on the basis that a plate a foot square and an inch thick weighs 40 lbs. for iron, 41 for steel, and 39 for cast iron, and 5 per cent. is added for rivets, the price often being made to cover the cost of the painting. In estimating the weights of the angle irons, etc., it may generally be assumed that the additional thickness at **A** (Fig. 83) is compensated for by the tapers at **BB**, but on page 168 a little extra has been allowed. In some cases the invoiced weights given by the makers are accepted, but it is more satisfactory to measure everything.

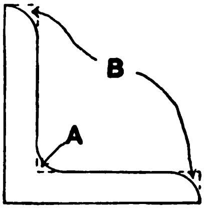

*FIG. 83.*

**Permanent Way.**—In measuring ballast no deduction is made for the sleepers, and in measuring the laying of permanent way, the dimensions are taken right through the points and crossings to allow for placing the sleepers, although the laying of the points and crossings is paid for in addition.

To further illustrate this subject, the quantities of the bridge given in Fig. 42 have been taken out, and are given below in detail. Quantity surveyors put their figures in a different way and make a separate abstract, but the method here given is more convenient, and saves time in making up the monthly certificates.

### EXCAVATION TO FOUNDATIONS.

| | ft. | in. | ft. | in. | ft. | in. | feet. | | |
|---|---|---|---|---|---|---|---|---|---|
| 2/- | 28 | 0 | 5 | 6 | 4 | 0 | 1,232 | | Abutments. |
| 6/- | 4 | 0 | 2 | 0 | 4 | 0 | 192 | | Counterforts. |
| 2/- | 2 | 3 | | 6¾ | 4 | 0 | 10 | | Portion of wing between face-line and footing-line of abutments. |
| 2/- | 18 | 6 | 5 | 6 | 4 | 4 | 882 | | Short wings— ft. in.<br>Short 1 6<br>Long 0 9<br>2 3 |
| 2/-½ | 4 | 6 | 3 | 6 | 4 | 0 | 63 | | Long wings, angle in front<br>6 0<br>5 0<br>2)11 0 |
| 2/-½ | 1 | 0 | 1 | 6 | 4 | 0 | 6 | | „ behind . 5 6 |
| 2/- | 28 | 3 | 5 | 6 | 4 | 4 | 1,346 | | „ main portion. |

27)3,731

138 yards cube

### DRY STONE WALLING.

| | ft. | in. | ft. | in. | ft. | in. | feet. | | |
|---|---|---|---|---|---|---|---|---|---|
| 2/- | 32 | 0 | 1 | 0 | 15 | 6 | 992 | | Behind abutments and counterforts. |
| 2/- | 5 | 6 | 1 | 0 | 17 | 0 | 187 | | Behind wings—<br>1 0<br>Top parts . . . . 4 6<br>5 6 |
| 2/- | 35 | 0 | 1 | 0 | 12 | 6 | 875 | | Sloping . . . . . 21 0<br>14 0<br>35 0 |
| 4/- | 3 | 0 | 1 | 0 | 8 | 0 | 96 | | Behind newels. |

27)2,150

80 yards cube

### RAMMING EARTH BEHIND ABUTMENTS, ETC.

| | ft. | in. | ft. | in. | ft. | in. | feet. | | |
|---|---|---|---|---|---|---|---|---|---|
| 2/- | 28 | 0 | 8 | 0 | 15 | 6 | 6,944 | | Behind abutments 4′ wide at the top, 12′ at the bottom. |
| 6/- | 6 | 0 | 1 | 9 | 15 | 6 | | 977 | Deduct counterforts. |
| 2/-½ | 3 | 0 | 4 | 0 | 15 | 6 | | 186 | „ corner of wing. |
| 2/- | 40 | 0 | 6 | 0 | 12 | 6 | 6,000 | | Add wings—<br>19 0<br>21 0<br>40 0 |
| 2/- | 88 | 0 | 1 | 0 | 3 | 0 | 528 | | „ over footings. |
| | | | | | | | 13,472 | 1,163 | |
| | | | | | | | 1,163 | | |

27)12,309

456 yards cube

### Brickwork.

| | ft. | in. | ft. | in. | ft. | in. | feet. | |
|---|---|---|---|---|---|---|---|---|
| 2/- | 88 | 0 | 0 | 4½ | 1 | 6 | 99 | Footing projections. |
| 2/- | 26 | 6 | 4 | 6 | 12 | 6 | 2,981 | Abutments. |
| 2/-½ | 26 | 6 | 12 | 9 | 5 | 6 | 1,859 | Spandrils. |
| 2/- | 40 | 0 | 2 | 3 | 1 | 0 | 180 | Spandril walls. |
| 2/- | 7 | 6 | 0 | 2¼ | | 6 | 1 | Sailing courses. |
| 2/- | 8 | 0 | 0 | 4½ | | 6 | 3 | „ „ |
| 6/- | 2 | 0 | 4 | 1½ | 19 | 6 | 966 | Counterforts. |
| 2/- | 2 | 0 | 3 | 4½ | 15 | 9 | 213 | Short wings between face of arch and top of slope. |
| 2/- | 2 | 0 | 4 | 10½ | 5 | 6 | 107 | Short wings between face of arch and top of slope. |
| 2/- | 14 | 0 | 3 | 0 | 11 | 3 | 945 | Short wings, sloping part. |
| 2/- | 14 | 0 | 4 | 1½ | 1 | 0 | 116 | „ „ „ „ |
| 2/- | 13 | 0 | 4 | 1½ | 1 | 3 | 134 | „ „ „ „ |
| 2/- | 10 | 6 | 4 | 6 | 2 | 3 | 213 | „ „ „ „ |
| 2/- | 4 | 6 | 4 | 10½ | 5 | 6 | 241 | „ „ „ „ |
| 2/-½-⅓ | 4 | 0 | 3 | 3 | 21 | 0 | 91 | Long wings, angle in front. (Note angles at back balance.) |
| 2/- | 5 | 0 | 3 | 4½ | 15 | 9 | 532 | Long wings, level portion. |
| 2/- | 5 | 0 | 4 | 10½ | 5 | 6 | 268 | „ „ „ „ |
| 2/- | 20 | 6 | 3 | 3¼ | 12 | 3 | 1,743 | „ „ sloping portion. |
| 2/-½ | 20 | 6 | 4 | 3½ | 9 | 0 | 792 | (Note.—This is taken assuming the width to be 2′ 3″ at the top and the back plumb.) |
| 2/-½-⅓ | 20 | 6 | 1 | 6 | 9 | 0 | 92 | |
| 4/- | 3 | 0 | 3 | 0 | 7 | 6 | 270 | Newels. |
| 4/- | 3 | 0 | 3 | 4½ | 2 | 3 | 91 | „ |
| 4/- | 3 | 0 | 3 | 9 | 2 | 3 | 101 | „ |
| 4/- | 3 | 0 | 4 | 1½ | 1 | 0 | 50 | „ |

27)12,088

447½ yards cube

### Brickwork in Arch.

| | | | | | | |
|---|---|---|---|---|---|---|
| 26 | 6 | 35 | 0 | 1 | 10½ | 27)1793 |

64½ yards cube

### Brickwork in Parapets.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2/- | 29 | 6 | 1 | 9 | 1 | 0 | 103 | Sailing course. Parapets. |
| 4/- | 5 | 6 | 2 | 1½ | 1 | 0 | 47 | „ „ Pilasters. |
| 2/- | 30 | 0 | 1 | 6 | 1 | 9 | 158 | Bottom plinth. Parapets. |
| 4/- | 5 | 0 | 1 | 10½ | 1 | 9 | 66 | „ „ Pilasters. |
| 2/- | 30 | 6 | 1 | 3 | 1 | 9 | 133 | Top plinth. Parapets. |
| 4/- | 4 | 6 | 1 | 7½ | 2 | 3 | 66 | „ „ Pilasters. |

27)573

21 yards cube

### Ashlar.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4/- | 3 | 6 | 3 | 6 | 1 | 0 | 49 | 0 | Newel caps. |
| 4/- | 5 | 0 | 1 | 10½ | 1 | 0 | 37 | 6 | Pilaster caps. |

87 feet cube

## ASPHALT.

| | ft. | in. | ft. | in. | feet | | ft. in. |
|---|---|---|---|---|---|---|---|
| | 18 | 6 | 40 | 0 | 740 | Over arch and spandrils— | <br>23 0<br>2/- 2 3 4 6<br>18 6 |
| 2/- | 2 | 0 | 4 | 1½ | 17 | „ counterforts. | |
| 2/- | 2 | 9 | 1 | 10½ | 10 | „ „ | |
| 2/- | 1 | 6 | 1 | 10½ | 6 | „ „ | |
| 2/- | 40 | 0 | 1 | 9 | 140 | „ face and top of spandril walls. | |
| 2/- | 40 | 6 | 1 | 0 | 81 | „ parapet to top of string course. | |

9)994

111 yards super.

## COPING.

| | ft. | in. | feet | | ft. in. |
|---|---|---|---|---|---|
| 2/- | 30 | 6 | 61 | Parapets. | |
| 2/- | 19 | 0 | 38 | Short wings. | |
| 2/- | 27 | 6 | 55 | Long wings— | 5 0<br>22 6<br>27 6 |

154 feet lineal

## PLINTH COURSE.

| | ft. | in. | feet | | ft. in. ft. in. | | ft. in. |
|---|---|---|---|---|---|---|---|
| 2/- | 45 | 6 | 91 | | 40 0 | | 40 6 |
| 2/- | 44 | 6 | 89 | 2/- 0 4½ | 0 9 | 2/- 0 4½ | 0 9 |
| | | | | 2/- 1 10½ | 3 9 | 2/- 2 1½ | 4 3 |
| | | | | | 44 6 | | 45 6 |

180 feet lineal

## BULL-NOSED QUOINS.

| | ft. | in. | feet | |
|---|---|---|---|---|
| 4/- | 11 | 0 | 44 | Main angles. |
| 8/- | 6 | 0 | 48 | Newels, front. |
| 4/- | 4 | 0 | 16 | „ back. |
| 4/- | 5 | 0 | 20 | Pilasters. Inside angles. |

128 feet lineal

In these quantities it will be noticed that in the case of the brickwork the two wings have been taken out in different ways. They would generally be taken out the same way, but the second system has been adopted to show another way of doing the same thing. It is necessary to make a front elevation to measure the coping on the sloping part of the wings, and also to take the lengths of the set-offs which cut out at the bottom.

**Weights and Measures.**—So many different standards of measurement are in use in this country alone that it has been thought well to give those that are commonly used by engineers in the appendix. This will be found useful in estimating and ordering materials, as, for instance, in the case of concrete for which the ballast is supplied by the yard, and the cement or lime by the bushel or ton.

**Estimates.**—To get anything like an accurate idea of the value of almost any kind of work it is necessary to split up each item into a number of heads, such as general charges, contingencies, contractor's profit, plant, machinery, horses, labour, materials, carriage and carting; and it is convenient to begin with the first of these as they are common to everything, and should be expressed in the form of a percentage, no amounts being put to the preliminary items in the quantities.

To get at the general charges a rough idea of the amount of labour, the total cost and the time the work will take to complete, is necessary. The chief things that come under this head are—

| | £ | *s.* | *d.* |
|---|---|---|---|
| Salaries of the contractor's agent, engineer, walking ganger, cashier, timekeeper, storekeeper, staff-holder, carpenter, smith and striker, watchmen, extra police, — weeks at — per week . . . . . | | | |
| Office rent, coals and lights and travelling expenses, — weeks at — per week . . . . . . . . . | | | |
| Buildings, stores, stables, carpenters' and smiths' shops, and tools and appliances for testing materials . . | | | |
| Men's huts, magazines for explosives, less value on completion . . . . . . . . . . . Gross | | | |
| Maintenance and repairing defects . . . . . . . | | | |
| Fees to local authorities, repairs to main and farm roads . . . . . . . . . . . . . . . . . | | | |
| Land for temporary purposes and access, and temporary fencing . . . . . . . . . . . . . . . | | | |

| | £ | s. | d. |
|---|---|---|---|
| Water supplies, including pipes, tank, pumps, and pumping, compensation, etc. | | | |
| Loss of interest on capital employed | | | |
| Fines owing to non-completion within the time named | | | |
| Fire insurance at ¼ per cent. on value of buildings | | | |
| Insurance of workmen against employers' liability and workmen's compensation risks at 2½ per cent. on £, gross wages | | | |
| Outside risk to persons not employed on the works at ½ per cent. on £, gross wages | | | |
| Total, equivalent to — per cent. on total cost | | | |
| Brought down | | | |
| Contingencies, including risk of damage to horses, buildings, gas and water mains, wires, railways, canals and other property, and damage from floods, the sea, slips, strikes, etc., at per cent. on gross cost | | | |
| Contractor's profit, depending on the extent of the work, and whether or no it is of such a nature as can be fairly estimated for at per cent. on gross cost | | | |
| Total per centum | | | |

These items only refer to the contractor's estimate. For the engineer's estimate allowance must be made for his fees and expenses, the salaries of the inspectors, legal expenses in buying the land, and the general charges for raising the capital, etc.

Such things as fencing are easy to get at. To the cost of the materials must be added something for waste, carriage and carting, the labour in fixing, and the above percentage, the value of the labour being the only unknown quantity, but it is small in proportion to the total, so that a slight error would neither prevent a contractor getting the work or making a profit out of it if he did.

With earthworks, however, the case is different. The cost depends on—

| | £ | s. | d. |
|---|---|---|---|
| General charges and profit at — per cent. . . . . . . | | | |
| Plant, including rails, fish-plates and bolts, sleepers, dogs, carting materials, planks, barrows, picks, drills, hammers, tip-waggons, locomotives, and steam navvies, all less value on completion to be divided by the total quantity of excavation to give the price per cubic yard . . . . . . . . . . | | | |
| Machinery and horses, including engine and horse drivers, cleaners, rope-runners, wheelmen to steam navvies, coal and stores to navvies and locomotives, repairs to machinery and waggons, insurance of horses, all at per day, and divided by the estimated quantity to be excavated per day; a separate estimate being made for each cutting . . . . . . . . . | | | |
| Explosives . . . . . . . . . @ per cubic yard | | | |
| Labour, including ganger, men in gullet and wings, and on road and tip, and boys at points in getting earth, laying in temporary roads, cleaning up after rain, and trimming, but not soiling, slopes of cuttings and banks . . . . . . . . @ per cubic yard | | | |
| | | | |

It is impossible to fill in any of these blanks without knowing the local conditions in each case, but the following notes may be found useful:—

Allowing for the value on completion, less carriage, a mile of temporary road may be put at £400 thus—

| | | £ |
|---|---|---|
| 88 tons, 56-lb. rails . . . | @ £2 10*s.* per ton | 220 |
| No. 1800 temporary sleepers | @ 1*s.* 4*d.* each . | 120 |
| 5 tons fastenings . . . . | @ £12 per ton . | 60 |
| | | £400 |

Carting may be put at 1*s.* a ton a mile, or 9*d.* if the distance is considerable.

Twelve sets of 3-yard waggons holding 2 yards of the solid can generally be got out per day with 4 men to each gullet, and 3 to each wing-waggon, in addition to the ganger and the men trimming the slopes. About 3 men would be required to keep a mile of road in order, and 4 men and 2 boys would be wanted at the tip-head to tip 150 waggons a day. Besides these 2 men a rope-runner, and perhaps a ton of coal, are required for the locomotives, and 2 horses and drivers for tipping, unless the lead is so short that the engine can tip the waggons itself.

A steam navvy can turn out 100 waggons a day on the average. It requires in addition to the horses and men on the tip 2 horses and drivers to bring the waggons to it, and some 30 men besides the driver, wheelman, and rope-runner, and uses about a ton of coal a day. The cost of a locomotive may be put at £600, and of a navvy at £1200, and 25 per cent. per annum allowed for repairs and depreciation; 8*s.* to 10*s.* may be put down per day for tip-horses and their drivers, harness, etc. For working a cutting by hand, it is sufficient to allow one barrow, pick, and 20-foot plank to each excavator per annum—that is to say, 2000 yards, or at the rate of a tenth of a penny per yard, for it must be remembered that there are 2 or 3 men to a barrow, and that a good deal of the work is done by casting direct into the waggons.

In excavating to foundations, allowance must be made for pumping by steam or hand, timber and labour in timbering, and in excavating and running the soil.

Three men on a 9-inch contractor's pump will remove a good deal of water, but if the springs are very strong a 5-inch centrifugal pump driven by an 8 H.P. portable engine burning 5 cwt. of coal a day may be required. Some foundations do not require timbering, but it is better generally to allow for inch poling-boards 3 feet long, with 9-inch × 3-inch walings, and 5-inch × 5-inch struts 6 feet apart, and to assume that these will only be used four times before they are knocked to pieces.

Four men will put in a 12-foot frame of timber in 3 hours, *i.e.* at the rate of 6*d.* per cubic foot for putting in and taking out. It makes very little difference what the width of the excavation is either in the cost of timber or the labour.

A foundation 6 feet wide would require the following timber:—

| | | ′ ″ | | ′ ″ | | ′ ″ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Walings . . | 2/- | 12·0 | × | 0·9 | × | 0·3 | = | 4½ | cubic feet |
| Poling-boards | 2/- | 12·0 | × | 3·0 | × | 0·1 | = | 6 | „ „ |
| Struts . . . | 3/- | 5·4 | × | 0·5 | × | 0·5 | = | 2¾ | „ „ |
| | | | | | | | | 13¼ | „ „ |

| | *s.* | *d.* |
|---|---|---|
| Now, 13¼ feet at 6*d.* gives . . . . . . . | 6 | 8 |
| And 4 men for 3 hours at 5*d.* gives . . . | 5 | 0 |
| Leaving for the taking out . . . . . . . . | 1 | 8 |

One man will usually get and cast up 10 yards a day if the depth is less than 6 feet, an extra man being required for each additional 6 feet or part of it. A steam crane would lift 100 yards per day if kept going.

In estimating for concrete, it must be remembered that the cement or lime is lost, and that at least 1¼ yards of ballast are required to make a cubic yard in the work, and perhaps 1½ yards if broken stone and sand are to be mixed together. Assuming that the proportions are to be 1 of cement to 6 of broken stone and 3 of sand, which would nearly represent 6 to 1 concrete, as the cement and sand would only just fill up the interstices in the broken stone, the cost of a cubic yard would be obtained as follows:—

| | £ | *s.* | *d.* |
|---|---|---|---|
| 1 cubic yard of stone, including royalty, getting, breaking, and carting . . . . . . . . . . . . | | | |
| ½ cubic yard of sand, including royalty, getting, washing, and carting . . . . . . . . . . . . | | | |
| ⅙ ton of cement, including cost at works, carriage, aerating, and carting . . . . . . . . . . . | | | |
| Labour in mixing, running, depositing, and ramming . | | | |
| 10 gallons of water . . . . . . . . . . . . | | | |

A cubic yard of cement is equal to 21 bushels, and so weighs just over a ton. A cubic yard of lime only weighs ⅔ ton, so that at 6 to 1 only $\frac{1}{9}$ ton would be required.

Allowing for waste and ⅜-inch mortar joints, a thousand 3-inch bricks, 8¾ inches long and 4¼ inches wide, are sufficient for 3 cubic yards of brickwork, so that the estimate for 1 cubic yard may be made out on the following basis:—

| | £ | s. | d. |
|---|---|---|---|
| 333⅓ bricks, including carriage, unloading, and carting at — per thousand . . . . . . . . . . . | | | |
| ⅛ ton cement, including carriage, carting, and aerating . | | | |
| ¼ cubic yard of sand, including getting, royalty, carting, and washing . . . . . . . . . . | | | |
| Labour . . . . . . . . . . . . . . . . . | | | |
| Add 15 per cent. if 2⅝-inch bricks are used instead of 3-inch . . . . . . . . . . . . . . . . | | | |
| Total . . . . . . . . . | | | |

Allowing for alternate headers and stretchers, 63 3-inch bricks are required for the face per super yard, on the assumption that sufficient false headers are used to make up for the facing bricks that are chipped or wasted.

The above figures are on the basis of 2 to 1 mortar. If the proportion is 3 to 1 only, $\frac{1}{10}$ ton of cement is required; and if 4 to 1, only $\frac{1}{12}$ ton.

If 2 to 1 lias mortar is employed only $\frac{1}{12}$ ton of lime is wanted; if 3 to 1, $\frac{1}{18}$ ton; and if 4 to 1, $\frac{1}{24}$ ton. Rather more mortar is required for masonry, but this depends on the size of the stone.

In estimating for timber work, from 5 to 10 per cent. must be allowed for waste, according as the scantlings are large or small.

The prices given by the manufacturers for girder-work fixed do not usually include the staging required for erection, so that allowance must be made for this in addition to the general charges.

Twenty-five per cent. must be added to the nett price of the ballast and road-stone to allow for consolidation, and if the thickness of metal is specified to be, say, 6 inches thick after rolling, 9 or 10 inches of the unconsolidated material must be provided for. A little allowance must be made for broken drain and water-pipes, but only a little.

For a square yard of artificial asphalt, about 28 lbs. of pitch, a gallon of tar, 3 lbs. of coke, and a little sand are required.

# APPENDICES

# APPENDIX A.

## PLANS FOR DEPOSITS.

### *Plan.*

THE name of the County or City must be written.

The name of the Division of the County must be written.

The name of each Parish, Township, or Hamlet must be written.

The County Boundaries must be shown, and the words "County Boundary" written on them.

The Parish Boundaries must be shown, and the words "Parish Boundary" written on them.

The Centre Lines must be shown, and the words "Centre Line of Railway" written on them.

The Limits of Deviation must be shown, and the words "Limit of Deviation" written on them.

The Cut Lines must be shown, and the words "Cut Line" written on them.

Mile and Furlong Points must be shown, and the figures 1 mile, 1, 2, etc., written on them.

The Radius of every curve under a mile radius must be written on it in furlongs and chains.

A number or link to every field, enclosure, road, river, etc., must be put.

Road Diversions must be shown by dotted lines, and the words "Proposed Diversion of Road" and "Road to be stopped" written.

In the case of tunnels, but *not* "cut and cover," the centre line must be dotted.

In the corner of the sheets the name of the railway must be put, the date, and the number of the sheet and railway, thus:

**B. & C. W. R.**
**November, 1901.**
**Sheet No. 6.**
**Railway No. 2.**

The scales must also be given, if they are not all put together on one sheet.

On the first sheet of each railway the words "Commencement of Railway No. —— and Junction with the —— and —— Railway" must be written, and a plan must be given showing the general direction and curves of the existing or authorized lines for 800 yards each side of the junction, existing railways being indicated by solid and authorized railways by dotted lines.

A mark thus **X** must be put at the Datum Point, and the words "Datum Point" written.

On the last sheet of each railway the words "Termination of Railway No. ——. Total length, —— miles, —— furlongs, —— chains," must be written, and, if necessary, "Junction with the —— and —— Railway."

The words "From ——" and "To ——" should be put on each main road or railway, and the names of all rivers, canals, railways, etc., as well as the north point, are generally given, although not required by the rules. However, if given, they must be correct.

Where the line runs along a street, like a tramway, the centre line of the street must be shown, and the distance from the centre line of the railway given; also the widths of the street, and a note must be put similar to that on p. 34 at the end of the section headed "Tramways."

### *Section.*

The words "Line corresponding with upper surface of rails" must be written on that line on each portion of the section.

The Mile and Furlong Points must be shown, and the figures 3 miles, 1, 2, 3, etc., written at them.

A solid vertical line at each change of gradient must be put, and the height in feet, and decimals of the rails above datum written upon it.

The words and figures "Horizontal," "Inclination, 1 in ——," must be written between these lines, and *be correct.* N.B.—When the cutline intersects a gradient, it is not necessary to repeat the words "Inclination, 1 in ——."

The extreme height of the rails above or below the ground in every embankment and cutting must be written in feet. N.B.—No height need be given if it is less than 5 feet in this case.

The height of the rails above or below the ground at the ends of every viaduct and tunnel, as well as the extreme height, must be given.

The height of the rails above or below the surface of every public road, railway, canal, and navigable river must be given in feet and inches, even if less than 5 feet.

The words "Tunnel, —— yards," or "Viaduct, —— yards, —— arches, —— span," must be written.

The words "Public road level unaltered," or "Public road to be raised (or lowered), —— feet, and crossed on the level, see cross-section No. ——," or "Public road to be raised (or lowered), —— feet, see cross-section No. ——," or similar words, must be written at the crossing of every road, railway, canal, and navigable river.

The span and headway of all under-bridges must be given in writing.

Whenever the level of any road, railway, etc., is altered, or when such is crossed on the level, a cross-section must be given, extending to a distance of 200 yards on each side of the centre line, and it is necessary to be careful in seeing that no mistake is made in numbering these.

The words "Rail Level" and "Railway Crosses" must be written, and respectively indicated by a thick horizontal line and a dotted vertical line.

The words "Inclination of Present road, 1 in ——," "Inclination of road when altered, 1 in —," must be written, and the figures "1 in —" and "1 in —" put on the lines representing the surfaces of the old and new roads respectively. The former must be calculated from, and written within, the portion of the road which it is proposed to alter.

The surface of the new road must be shown by a dotted line.

It is perhaps as well to give sections of road diversions in the same way as cross-sections.

In the corner of the sheet the name of the railway must be put, and also the session and the numbers of the sheet and railway, as on the plan.

The scales must also be given if they are not all put together on the first sheet.

On the first sheet of every railway the description of the datum line must be put thus: "Datum line 123·2 feet below the lower doorstep of ———, at the point marked **X** on the plan." N.B.—The datum line must be the same throughout but for a "Railway, No. 2," the description "Datum Line same as for Railway No. 1" is sufficient.

The words "Commencement of Railway No. —— and Junction with the, etc.," must be written on the first sheet, and "Termination of Railway No. —— and Junction with the ——. Total length, —— miles, —— furlongs, —— chains," on the last —— for each railway.

The gradients of existing or authorized lines must be given for a distance of 800 yards on each side the point of the junction when any other line is joined.

For subways the following must be put:—"Note: The Up and Down Lines of the Proposed Railway are intended to be placed in separate Tunnels, each circular in section and 12 feet internal diameter, with enlargements at the Stations, and it is proposed to afford access to the Railway by means of Stairs and Lifts or Inclines."

# APPENDIX B.

## Ordnance Survey Publications.

| Inches to a mile. | Feet to an inch. | Chains to an inch. | Ratio to full size. | Size of sheets. | Area represented. |
|---|---|---|---|---|---|
| 1, Old Series . . . | 5280·00 | 80·000 | 63,360 to 1 | Variable | Variable |
| 1, New Series . . | — | — | — | — | — |
| 1, Geological Survey | — | — | — | — | — |
| | | | | inches. | miles. |
| 6, County Maps . . | 880·00 | 13·333 | 10,560 to 1 | 36 × 24 | 6 × 4 |
| 25·344, Parish Maps | 208·33 | 3·157 | 2,500 „ 1 | 38 × 25 | 1·5 × 1 |
| | | | | | chains. |
| 60, London . . . | 88·00 | 1·333 | 1,056 „ 1 | 36 × 24 | 48 × 32 |
| 120, other towns . . | 44·00 | 0·666 | 528 „ 1 | 36 × 24 | 24 × 16 |
| 126·72, other towns. | 41·66 | 0·631 | 500 „ 1 | 38 × 25 | 24 × 16 |

There are also published indexes of the various scales and descriptions of the types used in the printing, abbreviations, symbols, boundaries, etc., as well as memoirs of the geological survey.

# APPENDIX C.

## PRINCIPAL BOARD OF TRADE RULES RELATING TO LIGHT RAILWAYS.

### *Notice of Proposed Application.*

2. THE notice must, in the case of a new railway, describe generally the line of the railway and its termini, the lands proposed to be taken (stating the quantity and the purpose for which it is proposed to take them), and the proposed gauge and motive power of the railway, and in the case of an application for an amending Order (so far as the amendment applied for does not relate to the power to make a new railway), the nature of the proposed amendment.

3. The advertisement must state the names of any counties or parishes through which the railway is to run.

4. Copies of the draft Order, and of the plan and book of reference and section, and of the estimate hereinafter mentioned, must be deposited by the promoters in the month in which the notice is advertised, with the clerk of the council of any *county, borough, district,* or *parish* in or through which any part of the railway is proposed to be made; and shall be open to inspection during office hours.

With the above documents there must also be deposited a sheet or sheets of the ordnance map, on the scale of not less than 1 inch to a mile, with the line of railway and its mile points indicated thereon, so as to show generally the course, length, and direction of the railway.

6. In cases where tidal lands within the ordinary spring tides are to be acquired or in any way affected, a copy of the plan and section with the ordnance map aforesaid, marked "Tidal Waters," shall, in the same month in which the notice is advertised, be deposited with the Fisheries and Harbour Department of the Board of Trade, and on such documents all tidal waters shall

be coloured blue; and if the plan includes any bridges across tidal waters, the dimensions as regards span and headway of the nearest bridges, if any, across the same tidal waters above and below the proposed new bridge shall be marked thereon.

In cases where the work is to be situate on the banks, foreshore, or bed of any river having a Board of Conservators, constituted by or under any Act of Parliament, similar documents shall in the same month be deposited with the Fisheries and Harbour Department of the Board of Trade and with the Conservators of that river, and if the plan includes any tunnel under or bridge over the river, the depth of such tunnel below the bed of the river or the span and headway of such bridge shall be marked thereon.

### *Plans, Book of Reference, and Sections.*

10. Every plan must be drawn to a scale of not less than 4 inches to the mile, and must describe the lands intended to be taken, and the line or situation of the whole of the railway (no alternative line or work being in any case permitted), and the lands in or through which it is to be made, or through which any communication to or from the railway shall be made.

11. Where it is the intention of the promoters to apply for powers to make any lateral deviation from the line of the proposed railway, the limits of such deviation shall be defined on the plan, and all lands included within such limits shall be marked thereon.

12. Unless the whole of such plan shall be upon a scale of not less than a quarter of an inch to every 100 feet, an enlarged plan shall be added of any building, yard, courtyard, or land within the curtilage of any building, or of any ground cultivated as a garden, either in the line of the proposed work, or included within the limits of the said deviation on a scale of not less than a quarter of an inch to every 100 feet.

13. The distances from one of the termini must be shown in miles and furlongs on the plan, and a memorandum of the radius of every curve not exceeding one mile in length shall be noted on the plan in furlongs and chains.

14. Where tunnelling as a substitute for open cutting is intended, the same shall be marked by a dotted line on the plan, and no work shall be shown as tunnelling in the making of which it will be necessary to cut through or remove the surface soil.

15. If it be intended to divert, widen, or narrow any public carriage road, navigable river, canal, or railway, the course of such diversion and the extent of such widening or narrowing shall be marked on the plan.

16. When a railway is intended to form a junction with an existing or authorized line of railway, the course of such existing or authorized line of railway shall be shown on the deposited plan for a distance of 800 yards on either side of the proposed junction on the same scale as the scale of the general plan.

17. If it be intended to lay any part of the railway along a road or street, the plan shall show at what distance from an imaginary line drawn along the centre of such road or street it is proposed to lay the rails; and the widths of such road or street shall at all material points be clearly marked in figures on the plan.

18. The book of reference shall contain the names of the owners or reputed owners, lessees or reputed lessees, and occupiers of all lands and houses in the line of the proposed railway or within the limits of deviation as defined on the plan, and shall describe such lands and houses respectively.

The book of reference shall also contain the name of the road authority of any road or street along which it is proposed to lay any part of the railway.

19. The section shall be drawn to the same horizontal scale as the plan, and to a vertical scale of not less than 1 inch to every 100 feet, and shall show the surface of the ground marked on the plan, the intended level of the proposed railway, the height of every embankment, and the depth of every cutting, and a datum horizontal line, which shall be the same throughout the whole length of the railway or any branch thereof respectively, and shall be referred to some fixed point (stated in writing on the section) near one of the termini of the railway.

In every section the line of the railway marked thereon shall correspond with the upper surface of the rails.

20. Distances on the datum line shall be marked in miles and furlongs, to correspond with those on the plan; a vertical measure from the datum line to the line of the railway shall be marked in feet and inches, or decimal parts of a foot, at the commencement and termination of the railway, and at each change of the gradient or inclination thereof; and the proportion or rate of inclination

between every two consecutive vertical measures shall also be marked.

21. Wherever the line of the railway is intended to cross any public carriage road, navigable river, canal, or railway, the height of the railway over or depth under the surface thereof, and the height and span of every arch of all bridges and viaducts by which the railway will be carried over the same, shall be marked in figures at every crossing thereof, and where the railway will be carried across any such public carriage road or railway, on the level thereof, such crossing shall be so described on the section, and it shall also be stated if such level will be unaltered.

22. If any alteration be intended in the water-level of any canal, or in the level or rate of inclination of any public carriage road or railway which shall be crossed by the railway, then the same shall be stated on the section, and each alteration shall be numbered; and cross-sections in reference to the numbers, on a horizontal scale of not less than 1 inch to every 330 feet, and on a vertical scale of not less than 1 inch to every 40 feet, shall be added, which shall show the present surface of such road, canal, or railway, and the intended surface thereof when altered; and the greatest of the present and intended rates of inclination of the portion of such road or railway intended to be altered shall also be marked in figures thereon, and where any public carriage road is crossed on the level, a cross-section of such road shall also be added; and all such cross-sections shall extend for 200 yards on each side of the centre line of the railway.

23. Wherever the extreme height of an embankment or the extreme depth of any cutting shall exceed 5 feet, the extreme height over or depth under the surface of the ground shall be marked in figures on the section; and if any bridge or viaduct of more than three arches shall intervene in any embankment, or if any tunnel shall intervene in any cutting, the extreme height or depth shall be marked in figures on each of the parts into which such embankment or cutting shall be divided by such bridge, viaduct, or tunnel.

24. Where tunnelling as a substitute for open cutting, or a viaduct as a substitute for solid embankment, is intended, the same shall be marked on the section, and no work shall be shown as tunnelling in the making of which it will be necessary to cut through or remove the surface soil.

25. When a railway is intended to form a junction with an

existing or authorized line of railway, the gradient of such existing or authorized line of railway shall be shown on the deposited section, and in connection therewith, and on the same scale as the general section, for a distance of 800 yards on either side of the point of junction.

# APPENDIX D.

THE Company shall carry the railway over the roads next hereinafter mentioned by means of a bridge of single span of not less than that hereinafter mentioned, and having a clear headway above the surface of the road for the space of 10 feet over such road of not less than that hereinafter mentioned (that is to say)—

| No. on plan. | Parish. | Span. | Height. |
|---|---|---|---|
| 11 | Kenwyn | 25 feet | 15 feet |

The Company shall carry the roads hereinafter mentioned over the railway by means of bridges of such width between the fences thereof as the Company think fit, not being less than the width hereinafter mentioned in connection therewith respectively (that is to say)—

| No. on plan. | Parish. | Description. | Width. |
|---|---|---|---|
| 26 | Kenwyn | Public road | 25 feet |

In altering for the purposes of the order the roads next hereinafter mentioned, the Company may make the same of any inclination not steeper than the inclination hereinafter mentioned in connection therewith (that is to say)—

| No. on plan. | Parish. | Description. | Intended inclination. |
|---|---|---|---|
| 88 | Kenwyn | Public road | 1 in 12 |

# APPENDIX E.

## ESTIMATE OF THE PROPOSED ——— RAILWAY.

Line No. —.

| | miles | fgs. | chs. |
|---|---|---|---|
| Length of line . . . | — | — | — |
| Gauge . . . . . . | — | — | — |

| | Cubic yards. | Price per yard. | Whether single or double. £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|---|---|
| Earthworks . . . . . | | | | | | | | |
| Cuttings—Rock . . . | | | | | | | | |
| Soft soil . . | | | | | | | | |
| Roads . . . | | | | | | | | |
| Total . | | | | | | | | |

Embankments, including roads, — cubic yards . . .
Bridges, public roads, number . . . .
Accommodation bridges and works . . . . . . .
Viaducts . . . . . . . . . . . . . . . . . . .
Culverts and drains . . . . . . . . . . . . .
Metallings of roads and level crossings . . . . . .
Gatekeepers' houses at level crossings . . . . . .
Permanent way, including fencing—

| miles | fgs. | chs. | | Cost per mile. £ | s. | d. |
|---|---|---|---|---|---|---|
| — | — | — | at | — | — | — |

Permanent way for sidings and cost of junctions . .
Stations . . . . . . . . . . . . . . . . . .

Contingencies, — per cent. . . . . . . . . . . . .

| | acres | roods | poles. | |
|---|---|---|---|---|
| Land and buildings, | — | — | — | . . . . . . . . . |

Total . .

The estimate to be as nearly as possible in accordance with this form for each railway, and a general summary of the different railways forming part of one order given at the end thus—

| | | |
|---|---|---|
| Line No. 1 . . . . . . . . | — | — |
| „ 2 . . . . . . . . | — | — |
| „ 3 . . . . . . . . | — | — |
| Total . . | — | — |

# APPENDIX F.

A GRADIENT of 1 in $x$, *i.e.* of $\frac{5280}{x}$ feet per mile, may be altered to $\frac{5280}{x} + 3$ feet per mile, and $\frac{5280}{x} + 3$ feet per mile is equivalent to a gradient of 1 in $\dfrac{5280}{\frac{5280}{x} + 3}$.

Assuming that the gradient 1 in $x$ may be altered to 1 in $(x - a)$, we get—

$$x - a = \frac{5280}{\frac{5280}{x} + 3}, \textit{ i.e. } x^2 - ax = 1760a$$ for gradients under 1 in 100

$$x - a = \frac{5280}{\frac{5280}{x} + 10}, \textit{ i.e. } \qquad = 528a$$ for gradients over 1 in 100

remembering that gradients of over 1 in 100 may be altered 10 feet instead of 3 feet per mile.

From this we find if $a = 1$, that $x = 42$ approximately, or that a gradient of 1 in 42 may be altered to 1 in 41. Putting $a = 2, 3, \ldots$ in succession, we get the following approximate table:—

| Gradient on deposited section. | Gradient which may be adopted in working section. |
|---|---|
| 1 in 40 | 1 in 39 |
| 1 „ 60 | 1 „ 58 |
| 1 „ 70 | 1 „ 67 |
| 1 „ 80 | 1 „ 76 |
| 1 „ 90 | 1 „ 85 |
| 1 „ 100 | 1 „ 95 |
| 1 „ 101 | 1 „ 85 |
| 1 „ 120 | 1 „ 98 |
| 1 „ 160 | 1 „ 123 |
| 1 „ 200 | 1 „ 145 |
| 1 „ 300 | 1 „ 191 |
| Horizontal | 1 „ 528 |

# APPENDIX G.

## Table of the most Convenient Gradients for Calculations.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | in | 1 | or | 66·00 | per chain | 1 | in | 100 | or | 0·66 | per chain |
| 1 | „ | 2 | „ | 33·00 | „ | 1 | „ | 110 | „ | 0·60 | „ |
| 1 | „ | 3 | „ | 22·00 | „ | 1 | „ | 120 | „ | 0·55 | „ |
| 1 | „ | 4 | „ | 16·50 | „ | 1 | „ | 132 | „ | 0·50 | „ |
| 1 | „ | 5 | „ | 13·20 | „ | 1 | „ | 150 | „ | 0·44 | „ |
| 1 | „ | 6 | „ | 11·00 | „ | 1 | „ | 165 | „ | 0·40 | „ |
| 1 | „ | 8 | „ | 8·25 | „ | 1 | „ | 176 | „ | 0·375 | „ |
| 1 | „ | 10 | „ | 6·60 | „ | 1 | „ | 200 | „ | 0·33 | „ |
| 1 | „ | 11 | „ | 6·00 | „ | 1 | „ | 220 | „ | 0·30 | „ |
| 1 | „ | 12 | „ | 5·50 | „ | 1 | „ | 240 | „ | 0·275 | „ |
| 1 | „ | 15 | „ | 4·40 | „ | 1 | „ | 264 | „ | 0·25 | „ |
| 1 | „ | 16 | „ | 4·125 | „ | 1 | „ | 300 | „ | 0·22 | „ |
| 1 | „ | 20 | „ | 3·30 | „ | 1 | „ | 330 | „ | 0·20 | „ |
| 1 | „ | 22 | „ | 3·00 | „ | 1 | „ | 400 | „ | 0·165 | „ |
| 1 | „ | 24 | „ | 2·75 | „ | 1 | „ | 440 | „ | 0·15 | „ |
| 1 | „ | 25 | „ | 2·64 | „ | 1 | „ | 528 | „ | 0·125 | „ |
| 1 | „ | 30 | „ | 2·20 | „ | 1 | „ | 550 | „ | 0·12 | „ |
| 1 | „ | 33 | „ | 2·00 | „ | 1 | „ | 600 | „ | 0·11 | „ |
| 1 | „ | 40 | „ | 1·65 | „ | 1 | „ | 660 | „ | 0·10 | „ |
| 1 | „ | 44 | „ | 1·50 | „ | 1 | „ | 825 | „ | 0·08 | „ |
| 1 | „ | 48 | „ | 1·375 | „ | 1 | „ | 880 | „ | 0·075 | „ |
| 1 | „ | 50 | „ | 1·32 | „ | 1 | „ | 1100 | „ | 0·06 | „ |
| 1 | „ | 55 | „ | 1·20 | „ | 1 | „ | 1200 | „ | 0·055 | „ |
| 1 | „ | 60 | „ | 1·10 | „ | 1 | „ | 1320 | „ | 0·05 | „ |
| 1 | „ | 66 | „ | 1·00 | „ | 1 | „ | 1650 | „ | 0·04 | „ |
| 1 | „ | 75 | „ | 0·88 | „ | 1 | „ | 2200 | „ | 0·03 | „ |
| 1 | „ | 80 | „ | 0·825 | „ | 1 | „ | 2640 | „ | 0·025 | „ |
| 1 | „ | 88 | „ | 0·75 | „ | 1 | „ | 3300 | „ | 0·02 | „ |

## APPEN-

### LIGHT RAIL-

| Name of Railway. | Gauge in feet. | Weight of rails per yard in lbs. | Sleepers. | | Steepest gra-dient, 1 in | Radius of sharpest curve in chains. |
|---|---|---|---|---|---|---|
| | | | Scant-ling in inches. | Length in feet. | | |
| 1. Rajpootana State Railway . | 3·28 | 40 | 8×4 | 6·00 | 150 | 15·0 |
| 2. Resiezka Ironworks, Hungary | 2·29 | 14 | — | — | 21·3 | 1·1 |
| 3. Firmy Ironworks . . . . | — | 32 | — | — | 22 | 2·5 |
| 4. Oldenburg . . . . . . | 2·46 | 25 | 8×4 | 4·25 | 330 | 12·5 |
| 5. Bilbao Ironworks . . . | 3·75 | 56 | 9×5 | 7·83 | 45 | 3·0 |
| 6. Szekul Mineral Railway, Hungary | 3·00 | 36 | 7×4 | 5·50 | — | 1·8 |
| 7. Tavaun Mineral Railway, France | 3·28 | 27 | — | — | 13·3 | 1·5 |
| 8. Eibenthal Mineral Railway | 2·50 | 12 | 8×6 | 4·50 | 20 | 1·0 |
| 9. South Australian Railway, Burra Extension | 5·25 | 40 | 9×4 | 9·00 | 80 | 20·0 |
| 10. South Australian Railway, Ports Augusta and Darwin | 3·50 | 40 | 8×4 | 6·50 | 50 | 5·0 |
| 11. New Zealand Railways . . | 3·50 | 40 | — | — | 20 | 5·0 |
| 12. New Zealand Railways, Fell Incline | 3·50 | 70 | — | — | — | — |
| 13. Ceylon . . . . . . . | 5·50 | 72 | 10×5 | 9·00 | 44 | 6·0 |
| 14. Northern Pacific . . . . | 4·71 | 56 | — | — | 45 | — |
| 15. Canadian Pacific . . . . | 4·71 | 56 | — | — | 132 | 22·0 |
| 16. Sydney Tramways . . . | 4·71 | 92 | — | — | 18 | 1·5 |
| 17. Cape Railways . . . . | 3·50 | 45 | 9×4 | 7·00 | 40 | 6·0 |
| 18. Light Italian Railways . . | 2·77 | 45 | 6×5 | 5·25 | 20 | 2·5 |
| 19. Narrow Gauge, Saxony . . | 2·46 | — | — | — | 60 | 4·0 |
| 20. Prussian Narrow Gauge . | 1·96 | 19 | — | 4·00 | 25 | 1·5 |
| 21. Wengernalp Railway . . | 2·62 | 41 | — | 5·25 | — | 3·0 |
| 22. Argentine . . . . . . | 3·28 | 32 | 8×4 | 6·50 | 80 | 6·0 |
| 23. „ feeder lines . . | 1·64 | 14 | 6×4 | 3·25 | 60 | 0·5 |
| 24. Steam Trams in Italy . . | 4·71 | 42 | 7×4 | 7·25 | 17 | 1·0 |
| 25. Palermo Light Railway . . | 3·28 | 40 | 7×4 | 5·50 | 25 | 4·0 |
| 26. South-West Venezuela . . | 2·00 | — | — | — | 28·5 | 3·0 |
| 27. Congo . . . . . . . | 2·50 | — | — | — | — | — |
| 28. North-East Dundas Tramway, Tasmania | — | 46 | — | — | 27 | 1·5 |
| 29. Chinipas Mineral . . . . | 2·50 | 35 | — | 3·50 | 25 | 2·0 |
| 30. Anglo-Chilian Nitrate . . | 3·50 | 40 | 8×4 | 7·00 | 25 | 3·0 |
| 31. Australian Light Railways . | 2·00 | 24 | 8×4 | 4·50 | 200 | 1·5 |
| 32. „ Horse Lines . . | 2·00 | 14 | — | — | — | — |
| 33. Tocopilla Railway . . . | 3·50 | 40 | — | — | 25 | 3·0 |

# DIX H.

## WAY EXAMPLES.

| Formation width in feet. | Engines. | | Load drawn up steepest gradient. | Reference to the *Minutes of Proceedings of the Institution of Civil Engineers.* | | Notes. |
|---|---|---|---|---|---|---|
| | Weight on driving-wheels. | Max. weight per axle. | | | | |
| | tons. | tons. | tons. | vol. | page. | |
| 12 | — | 6 | — | l. | 148 | Formation of cuttings, 16 feet |
| — | 4·5 | 2·25 | 22 | „ | 247 | Load drawn at 4·3 miles an hour |
| — | 5 | 2·50 | 5 | „ | 246 | 60 tons drawn on the level |
| — | 7·5 | 3·75 | — | „ | 244 | |
| — | 24 | 8 | 110 | li.. | 237 | |
| 10 | 12 | 6 | — | lii. | 320 | |
| 7 | 7·5 | 3·75 | 9·7 | „ | „ | |
| 7 | — | — | — | „ | „ | |
| 18 | 26 | 9 | — | lvi. | 26 | Formation of cuttings, 16·5, rails too weak |
| 14 | 14·75 | 5·25 | 85 | „ | „ | Formation of cuttings, 12·5 |
| — | — | — | — | „ | 88 | |
| — | 36 | — | 14 | lxiii. | 50 | 63 tons taken up by grip |
| — | 22 | — | 77 | „ | 66 | Incline 18 miles long, reducted to 1 in 51 on sharp curves |
| — | — | — | — | lxxv. | 1 | |
| 14 | — | — | — | lxxvi. | 266 | |
| — | — | 6 | — | lxxix. | 120 | |
| — | 30 | 10 | — | lxxxi. | 252 | |
| 11 | 17 | — | 25 | lxxxiii. | 506 | Speed, 6½ miles an hour |
| — | — | 5 | — | lxxxvi. | 414 | |
| — | 15 | — | 30 | cxvi. | 438 | Speed, 10 miles an hour |
| 9 | — | — | — | cxvii. | 446 | |
| 11·5 | 20 | 10 | — | cxviii. | 375 | |
| — | — | — | — | „ | „ | |
| — | 16 | — | — | cxix. | 347 | |
| — | 20 | — | 50 | cxxiv. | 335 | |
| — | 20 | — | 64 | „ | „ | |
| — | — | — | — | cxxxv. | 190 | |
| — | 14 | — | 50 | cxl. | 157 | |
| — | — | — | — | cxiii. | 268 | |
| 9 | 36 | 9 | — | cxv. | 326 | |
| 10 | 10 | 5 | — | cxxii. | 202 | |
| — | — | — | — | „ | „ | |
| — | 34 | — | 65 | cxlii. | 91 | Steepest gradient on the 3-chain curve, 1 in 33 |

# APPENDIX I.

## EXAMPLES OF STEEP GRADIENTS WORKED BY ADHESION.

| | Reference to *Min. Proc. Inst. C.E.* | Steepest gradient. | Weight on driving wheels. | Load drawn up gradient. | Load drawn up gradient including engine, etc. |
|---|---|---|---|---|---|
| | vol. page | | tons. | tons. | tons. |
| Mauritius Railways | lxiii. 55 | 1 in 27 | 37 | 60 | — |
| „ „ | „ „ | 1 „ 27 | 48 | 83 | — |
| Indiana . . . . | „ „ | 1 „ 16·5 | 50 | 50 | — |
| Mont Cenis temporary line | „ 97 | 1 „ 12·5 | 21 | 24 | — |
| Kadugannawa incline, Ceylon | „ 64 | 1 „ 45 | 32·5 | 143 | 199 |
| Taff Vale . . . | „ 103 | 1 „ 18 | 36 | 45 | 81 |
| Oldham . . . . | „ „ | 1 „ 27 | 29 | 60 to 80 | — |
| Denver and Rio Grande | lxxxv. 69 | 1 „ 22 | — | — | — |
| Mexican Railway, incline 14 miles long | xcvi. 160 | 1 „ 25 | 70 | 153 | — |
| Tocopilla Railway | cxlii. 91 | 1 „ 25<br>1 „ 33 | 34 | 65 | 117 |
| „ „ | „ „ | 1 „ 33 | 16 | 20 | 36 |
| „ „ | „ „ | 1 „ 33 | 57 | 120 | 177 |
| „ „ | „ „ | 1 „ 33 | 53·5 | 120 | 173·5 |
| „ „ | „ „ | 1 „ 33 | 27 | 50 | 87 |
| New South Wales . | cxx. 35 | 1 „ 40 | 34 | 275 | 364 |
| Indian State . . | „ „ | 1 „ 40 | 87 | 450 | 578 |
| St. Gothard . . . | „ „ | 1 „ 37 | 84 | 200 | 284 |
| Darjeeling . . . | „ 36 | 1 in 28 for 40 miles | 14 | 35 | 49 |
| La Guaira, Venezuela | „ „ | 1 in 27 for 23 miles | 27 | 68 | 102 |
| Mexican . . . . | „ „ | 1 in 25 for 14 miles | 92 | 175 | 267 |
| Yverdon, St. Croix, Switzerland | „ 37 | 1 in 22 | 34 | 60 | 94 |
| Madison . . . . | „ 125 | 1 „ 17 | 47 at | 5 miles an hr. | 175 |
| „ . . . . . . | „ „ | 1 „ 17 | 50 „ | 6 „ „ | 187 |
| „ . . . . . . | „ „ | 1 „ 17 | 50 „ | 14 „ „ | 89 |
| A. Beyer and Peacock | „ 75 | 1 „ 100 | 42 „ | 35 „ „ | 325 |
| „ „ | „ „ | 1 „ 100 | 42 „ | 15 „ „ | 670 |
| „ „ | „ „ | 1 „ 75 | 42 „ | 30 „ „ | 330 |
| „ „ | „ „ | 1 „ 75 | 42 „ | 12 „ „ | 575 |
| „ „ | „ „ | 1 „ 60 | 42 „ | 25 „ „ | 340 |
| „ „ | „ „ | 1 „ 60 | 42 „ | 10 „ „ | 485 |
| „ „ | „ „ | 1 „ 40 | 42 „ | 20 „ „ | 295 |
| „ „ | „ „ | 1 „ 40 | 42 „ | 10 „ „ | 345 |
| | „ „ | | | | |

# APPENDIX K.

## PERMANENT-WAY ESTIMATES PER MILE.

*No.* 1.—84-*lb. Bull-headed Rails in* 30-*foot lengths on* 8 *foot* 11 *inch* × 10-*inch* × 5-*inch Sleepers, with compressed fir Keys and* 42-*lb. Chairs.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 132 | 0 | Rails . . . . . . . . . . . | £5 | 660 | 0 | 0 |
| 4 | 2 | Fish plates, 352 pairs, at 26 lbs. | £8 | 32 | 16 | 0 |
| 0 | 19 | „ bolts, 1408, „ 1½ „ | £12 | 11 | 8 | 0 |
| 72 | 12 | Chairs, 3872, „ 42 „. | £4 | 290 | 8 | 0 |
| 4 | 7 | Spikes, ⅞" × 7", 7744, „ 1¼ „ | £8 | 34 | 16 | 0 |
| | | 7744 trenails, 1¼" × 7", at 1/3 lb. 1 ton 3 cwts. . . . . . . . | £4 ‰ | 31 | 0 | 0 |
| | | 3872 keys, 7" long, at 1½ lb. 2 tons 12 cwts. . . . . . . . . . | £5 ‰ | 19 | 7 | 0 |
| | | 1936 sleepers,[1] at 1¼ cwt., 121 tons | 4/6 each | 435 | 12 | 0 |
| 339 | | Carriage of materials. . . . . . . | 5/- | 84 | 15 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . . | 1/- | 88 | 0 | 0 |
| Cube yds. | | | | | | |
| 2640 | | Bottom ballast, 13' 6" wide, 12" deep | 3/- | 396 | 0 | 0 |
| 980 | | Top „ 12' „ 5" „ | 4/- | 196 | 0 | 0 |
| | | | | £2280 | 2 | 0 |

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[1] A saving of £28 16*s*. can be effected by using steel sleepers thus—

130 tons steel sleepers, $\frac{5}{16}$" thick, at 150 lbs. each, at £6, £780.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| | | | | 780 | 0 | 0 |
| Cr. Sleepers . . . . . . . . | 435 | 12 | 0 | | | |
| Chairs . . . . . . . . . | 290 | 8 | 0 | | | |
| Spikes . . . . . . . . . | 34 | 16 | 0 | | | |
| Trenails . . . . . . . . | 31 | 0 | 0 | | | |
| Carriage . . . . . . . . | 17 | 0 | 0 | | | |
| | | | | 808 | 16 | 0 |

### *No. 2.—91-lb. Barlow Rails in 20-foot lengths.*

| tons cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| 143 0 | Rails | £5 | 715 | 0 | 0 |
| 13 4 | Saddles, 528, at 56 lbs. | £8 | 105 | 12 | 0 |
| 6 12 | Ties L.I., 264, „ 56 „ | £8 | 52 | 16 | 0 |
| 2 7 | Bolts and nuts, 4224, „ 1¼ „ | £12 | 28 | 4 | 0 |
| 166 0 | Carriage of materials | 5/- | 41 | 10 | 0 |
| Lin. yds. | | | | | |
| 1760 | Laying and packing | 9*d*. | 66 | 0 | 0 |
| Cube yds. | | | | | |
| 1760 | Bottom ballast, 9' wide, 12" deep | 3/- | 264 | 0 | 0 |
| 440 | Top „ 9' „ 3" „ | 4/- | 88 | 0 | 0 |
| | | | £1361 | 2 | 0 |

### *No. 3.—70-lb. Bridge Rails on Longitudinal Timbers.*

| tons cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|
| 110 0 | Rails, in 30' lengths | £5 | 550 | 0 | 0 |
| 1 2 | Ridged joint plates, 12" long, 352, at 7 lbs. | £8 | 8 | 16 | 0 |
| 0 8 | Timber joint plates, 704, at 1¼ lbs. | £8 | 3 | 4 | 0 |
| 7 10 | Fang bolts, 6688, „ 2½ „ | £12 | 90 | 0 | 0 |
| 3 15 | Strap bolts and nails, 960, „ 8¾ „ | £12 | 45 | 0 | 0 |
| Cube ft. | | | | | |
| 7186 | 14" × 7" creo. pine, in 30' lengths, at 42 lbs. 133 tons | 3/- | 1077 | 18 | 0 |
| 467 | 7" × 5" creo. pine, for transoms, 11' apart, at 42 lbs. 9 tons | 3/- | 70 | 1 | 0 |
| Super sqs. | | | | | |
| 71 | 1" pine packing, 8" wide, at 3 cwt. 10 tons | 10/- | 35 | 10 | 0 |
| tons. | | | | | |
| 276 | Carriage of materials | 5/- | 69 | 0 | 0 |
| Lin. yds. | | | | | |
| 1760 | Laying and packing | 1/3 | 110 | 0 | 0 |
| Cube yds. | | | | | |
| 2053 | Bottom ballast, 10' 6" wide, 12" deep | 3/- | 307 | 19 | 0 |
| 880 | Top „ 9' „ 6" „ | 4/- | 176 | 0 | 0 |
| | | | £2543 | 8 | 0 |

### *No.* 4.—84-*lb. Vignoles Rails in* 30-*foot lengths.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 132 | 0 | Rails . . . . . . . . . . . . . | £5 | 660 | 0 | 0 |
| 4 | 2 | Fish plates, 352 pairs, at 26 lbs. . . | £8 | 32 | 16 | 0 |
| 0 | 19 | „ bolts, 1408, „ 1½ „ . . | £12 | 11 | 8 | 0 |
| 7 | 15 | Fang bolts, 7744, „ 2¼ „ . . | £12 | 93 | 0 | 0 |
| 4 | 6 | Clips, 7744, „ 1¼ „ . . | £12 | 51 | 12 | 0 |
| | | 1936 sleepers, at 1¼ cwt. 121 tons . | 4/6 | 435 | 12 | 0 |
| 270 | 0 | Carriage of materials . . . . . | 5/- | 67 | 10 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . | 1/- | 88 | 0 | 0 |
| Cube yds. | | | | | | |
| 2640 | | Bottom ballast . . . . . . . . | 3/- | 396 | 0 | 0 |
| 980 | | Top „ . . . . . . . . | 4/- | 196 | 0 | 0 |
| | | | | £2031 | 18 | 0 |

### *No.* 5.—70-*lb. Vignoles Rails in* 30-*foot lengths.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 110 | 0 | Rails . . . . . . . . . . | £5 | 550 | 0 | 0 |
| 2 | 10 | Fish plates, 352 pairs, at 16 lbs. | £8 | 20 | 0 | 0 |
| 0 | 13 | „ bolts, 4″×¾″, 1408, „ 1 „ | £12 | 7 | 16 | 0 |
| 5 | 4 | Fang bolts, 6½″×⅝″, 7744, „ 1½ „ | £12 | 62 | 8 | 0 |
| 4 | 6 | Clips, 7744, „ 1¼ „ | £12 | 51 | 12 | 0 |
| | | 1936 sleepers, 9″ × 4½″, at 1 cwt. 97 tons . . . . . . . . . | 3/- | 290 | 8 | 0 |
| 220 | 0 | Carriage of materials . . . . . | 5/- | 55 | 0 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . | 1/- | 88 | 0 | 0 |
| Cube yds. | | | | | | |
| 2640 | | Bottom ballast, 13′ 6″ wide, 12″ deep | 3/- | 396 | 0 | 0 |
| 980 | | Top, „ 12′ „ 5″ „ | 4/- | 196 | 0 | 0 |
| | | | | £1717 | 4 | 0 |

### *No.* 6.—56-*lb. Vignoles Rails in* 24-*foot lengths.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 88 | 0 | Rails . . . . . . . . . . . . | £5 10/- | 484 | 0 | 0 |
| 2 | 7 | Fish plates, 440 pairs, at 12 lbs. . | £9 | 21 | 3 | 0 |
| 0 | 12 | „ bolts, 1760, „ ¾ „ . | £14 | 8 | 8 | 0 |
| 4 | 9 | Fang bolts,[1] 7920, „ 1¼ „ . | £14 | 62 | 6 | 0 |
| 3 | 11 | Clips, 7920, „ 1 „ . | £14 | 49 | 14 | 0 |
| | | 1980 sleepers, 9 to a rail, 9' × 9" × 4½" HR. at 1 cwt. 99 tons . . . . | 2/3 | 222 | 15 | 0 |
| 198 | 0 | Carriage of materials . . . . . | 5/- | 49 | 10 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . | 9*d.* | 66 | 0 | 0 |
| Cube yds. | | | | | | |
| 1760 | | Bottom ballast, 12' wide, 9" deep . | 3/- | 264 | 0 | 0 |
| 770 | | Top „ 10' 6" „ 4½" „ . | 4/- | 154 | 0 | 0 |
| | | | | £1381 | 16 | 0 |

### No. 7.—42-*lb. Vignoles Rails in* 24-*foot lengths,* 4-*foot* 8½-*inch gauge.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 66 | 0 | Rails . . . . . . . . . . . . | £5 10/- | 363 | 0 | 0 |
| 2 | 0 | Fish plates, 440 pairs, at 10 lbs. . | £9 | 18 | 0 | 0 |
| 0 | 12 | „ bolts, 1760, „ ¾ „ . | £14 | 8 | 8 | 0 |
| 1 | 0 | Fang bolts,[1] 1760, „ 1¼ „ . | £14 | 14 | 0 | 0 |
| 0 | 16 | Clips 1760, „ 1 „ . | £14 | 11 | 4 | 0 |
| 1 | 8 | Dogs, 4½" × ⅝", 6160, „ ½ „ . | £9 | 12 | 12 | 0 |
| | | 1980 sleepers, 9 to a rail, 9' × 9" × 4½" HR. at 1 cwt. 99 tons . . . . | 2/3 | 222 | 15 | 0 |
| 171 | 0 | Carriage of materials . . . . . . | 5/- | 42 | 15 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . | 9*d.* | 66 | 0 | 0 |
| Cube yds. | | | | | | |
| 1760 | | Bottom ballast, 12' wide, 9" deep . . | 3/- | 264 | 0 | 0 |
| 770 | | Top „ 10' 6" „ 4½" „ . . | 4/- | 154 | 0 | 0 |
| | | | | £1176 | 14 | 0 |

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[1] Triangular fangs, 2" side, ½" bolts.

### No. 8.—42-*lb.* *Rails as above for* 3-*foot gauge.*

| | | | £ | s. | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| | Estimate as above . . . . . . . | | | | 1176 | 14 | 0 |
| | 1980 sleepers at 1/9 instead of 2/3. Saving, 6*d.* | | 49 | 10 | | | |
| Cube yds. | | | | | | | |
| 440 | Bottom ballast less | „ 3/- | 66 | 0 | | | |
| 220 | Top „ „ | „ 4/- | 44 | 0 | | | |
| | | | ——— | | 159 | 10 | 0 |
| | | | | | £1017 | 4 | 0 |

### No. 9.—28-*lb.* *Vignoles Rails in* 18-*foot lengths,* 3-*foot gauge.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 44 | 0 | Rails . . . . . . . . . . . . . | £6 | 264 | 0 | 0 |
| 1 | 0 | Fish plates, 588 pairs, at 4 lbs. . . . | £9 | 9 | 0 | 0 |
| 0 | [illegible] | „ bolts, 2352, „ ¼ „ . . . | £14 | 4 | 4 | 0 |
| 1 | 1 | Fang „ 2348, „ 1 „ . . . | £14 | 14 | 14 | 0 |
| 1 | 1 | Clips, 2348, „ 1 „ . . . | £14 | 14 | 14 | 0 |
| 0 | 16 | Dogs, 4696, „ ⅜ „ . . . | £9 | 7 | 4 | 0 |
| | | 1760 sleepers, 6′ × 8″ × 4″ HR. at ½ cwt. 44 tons . . . . . . . . . . . | 1/9 | 154 | 0 | 0 |
| 92 | 0 | Carriage of materials . . . . . . . | 5/- | 23 | 0 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . . | 6*d.* | 44 | 0 | 0 |
| 880 | | Bottom ballast, 9′ wide, 6″ deep . . | 3/- | 132 | 0 | 0 |
| 488 | | Top „ 7′ 6″ „ 4″ „ . . . | 4/- | 97 | 12 | 0 |
| | | | | £764 | 8 | 0 |

### No. 10.—14-*lb. Vignoles Rails in* 15-*foot lengths*, 2-*foot* 6-*inch gauge.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 22 | 0 | Rails . . . . . . . . . . . . . . | £6 | 132 | 0 | 0 |
| 0 | 13 | Fish plates, 1" × ¼", 704 pairs, at 2 lbs. | £9 | 5 | 17 | 0 |
| 0 | 3 | „ bolts, 1½"×½", 2816, „ ⅛ lb. | £14 | 2 | 2 | 0 |
| 1 | 6 | Dogs, 7744, „ ⅜ lb. | £9 | 11 | 14 | 0 |
| | | 1760 sleepers, 4' 6"×9"×4½". HR. at ⅓ cwt. 30 tons . . . . . . . . | 1/3 | 110 | 0 | 0 |
| 20 | | Carriage of material . . . . . . . . | 5/- | 5 | 10 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying and packing . . . . . . . . | -/6 | 44 | 0 | 0 |
| 733 | | Bottom ballast, 7' 6" wide, 6" deep . . | 3/- | 109 | 19 | 0 |
| 495 | | Top „ 6' 9" „ 4½" „ . . | 4/- | 99 | 0 | 0 |
| | | | | £528 | 2 | 0 |

### No. 11.—84-*lb. Tramway Rails in* 30-*foot lengths*, 4-*foot* 8½-*inch gauge.*

| tons | cwts. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| 132 | 0 | Rails . . . . . . . . . . . . . . | £5 | 660 | 0 | 0 |
| 4 | 2 | Fish plates, 352 pairs, at 26 lbs. | £8 | 32 | 16 | 0 |
| 0 | 19 | „ bolts, 1408, „ 1½ „ | £12 | 11 | 8 | 0 |
| 4 | 8 | Tie bars, 2" × ⅜", 704, „ 14 „ | £12 | 52 | 16 | 0 |
| 1392 | 5 | Carriage of materials . . . . . . . | 5/- | 34 | 16 | 0 |
| Cube yds. | | | | | | |
| 1760 | | Excavation and carting away . . . | 3/- | 264 | 0 | 0 |
| 880 | | Concrete, 6" thick . . . . . . . . | 20/- | 880 | 0 | 0 |
| Sup. yds. | | | | | | |
| 4400 | | Pitching with granite setts, 5" deep on sand . . . . . . . . . . . | 12/6 | 2750 | 0 | 0 |
| Lin. yds. | | | | | | |
| 1760 | | Laying permanent way . . . . . | 1/- | 88 | 0 | 0 |
| | | | | £4773 | 16 | 0 |

*Steel sleepers for* 14-*lb. rail*, 2-*foot* 6-*inch gauge.*

| | |
|---|---|
| 11 tons in 1760, 3' 6" long, 5" wide, 1' deep, $\frac{3}{16}$" thick, *i.e.* with clips 3' 9" × 6" × 7½ lbs. = 14 lbs. each at £8 . . . . . . . . . | £88 |

# APPENDIX L.

## ESTIMATE FOR PLATELAYER'S COTTAGE.

| yds. | ft. | | @ | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|
| Super. | | | | | | |
| 84 | 0 | Clearing and levelling surface, and wheeling away soil, rubbish, and surplus earth to a distance of not more than 20 yards | 1*d.* | 0 | 7 | 0 |
| Cube. | | | | | | |
| 17 | 0 | Excavation to foundations, filling and ramming over footings, and wheeling away surplus as above | 1/- | 0 | 17 | 0 |
| 7 | 0 | Concrete in foundations 6″ thick, 1 of blue lias lime to 6 of ballast | 8/- | 2 | 16 | 0 |
| Super. | | | | | | |
| 30 | 0 | Forming paths with gravel 4″ thick and rolling | 8*d.* | 1 | 0 | 0 |
| 15 | 0 | 3″ cement concrete floors and hearths, 1 of cement to 8 of ballast finished with 1 of cement to 2 of sand ½″ thick | 2/4 | 1 | 15 | 0 |
| Lin. | | | | | | |
| 2 | 0 | 9″ × 6″ cement doorsteps as above | 2/6 | 0 | 5 | 0 |
| 2 | 0 | 4½″ × 6″ ditto | 2/- | 0 | 4 | 0 |
| 10 | 0 | 4″ glazed socketed stoneware drain-pipes jointed in cement laid 2′ deep to a fall of 1″ in 8′. P.C. 9*d.* | 1/9 | 0 | 17 | 6 |
| 5 | 0 | Ditto. Ditto from D.P.'s to cistern | 1/9 | 0 | 8 | 9 |
| | | 1 junction. P.C. 6*d.* extra | 8*d.* | 0 | 0 | 8 |
| | | 4 bend. „ 3*d.* „ | 4*d.* | 0 | 1 | 4 |
| | | 2-4″ gulleys. „ 2/3 with grate | 3/- | 0 | 6 | 0 |
| | | 1 salt-glazed sink 30″ × 18″. P.C. 6/- | 7/6 | 0 | 7 | 6 |
| | | Sink-pipe 3″ diameter. P.C. 1/4 | 2/6 | 0 | 2 | 6 |
| | | Carried forward | | £9 | 8 | 3 |

| yds. | ft. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| Cube. | | Brought forward . . . | | 9 | 8 | 3 |
| 64 | 0 | Brickwork in mortar in 9″ walls, chimneys, and footings . . . . . . . . . | 22/- | 70 | 8 | 0 |
| 11 | 0 | Ditto in 4½″ walls and footings . . . . | 24/- | 13 | 4 | 0 |
| Super. | | | | | | |
| 228 | 0 | Extra to picked face and flat pointing . | 9*d.* | 8 | 11 | 0 |
| 112 | 0 | Twice limewhiting to w.c., coals, cupboard, and scullery . . . . . . . | 2*d.* | 0 | 18 | 8 |
| Lin. | | | | | | |
| 11 | 0 | Fair skew-cutting to 9″-wall . . . . . | 1/- | 0 | 11 | 0 |
| 7 | 0 | Ditto to 4½″-wall . . . . . . . . | 9*d.* | 0 | 5 | 3 |
| 70 | 0 | Bedding wall-plates in mortar . . . . | 1*d.* | 0 | 5 | 10 |
| 35 | 0 | Cement, damp course, 9″ wide, ¾″ thick . | 6*d.* | 0 | 17 | 6 |
| 12 | 0 | Ditto, 4½″ wide . . . . . . . . . . | 3*d.* | 0 | 3 | 0 |
| 8 | 0 | Brick on edge window-sills with cement throating under . . . . . . . . | 1/- | 0 | 8 | 0 |
| 15 | 0 | Extra to sailing courses . . . . . . | 4*d.* | 0 | 5 | 0 |
| 6 | 0 | Raking out and pointing to lead flashings . . . . . . . . . . . . | 1/- | 0 | 6 | 0 |
| | | 7 flues cored . . . . . . . . . . | 1/6 | 0 | 10 | 6 |
| | | 48 ends of joists and pinned . . . . . | 3*d.* | 0 | 12 | 0 |
| | | 72 rafters ditto . . . . . . . . . . | 3*d.* | 0 | 18 | 0 |
| | | 4 door-frames set and pointed . . . . | 1/6 | 0 | 6 | 0 |
| | | 6 large window-frames ditto . . . . . | 1/6 | 0 | 9 | 0 |
| | | 2 small „ „ . . . . . .<br>1 „ door-frame „ to w.c. . . | 1/- | 0 | 3 | 0 |
| | | 1 copper set . . . . . . . . . . . | 3/- | 0 | 3 | 0 |
| | | 1 kitchen-range ditto . . . . . . . | 10/- | 0 | 10 | 0 |
| | | 2 sets of bars set in scullery . . . . .<br>1 furnace-door ditto . . . . . . . | 1/- | 0 | 3 | 0 |
| | | 4 register stoves set . . . . . . . | 3/- | 0 | 12 | 0 |
| | | 10 straight arches formed over doors and windows, including cambers, and forming skew-backs. . . . . . . . . | 2/- | 1 | 0 | 0 |
| | | 6 air-bricks. P.C. 4*d.* . . . . . . . . | 1/6 | 0 | 9 | 0 |
| | | 40 ends of lintels bedded . . . . . . | 3*d.* | 0 | 10 | 0 |
| Cube. | | | | | | |
| 11 | 0 | Excavation for cistern . . . . . . . | 1/- | 0 | 11 | 0 |
| 1 | 0 | 8 to 1 cement concrete, bottom 9″ thick . | 18/- | 0 | 18 | 0 |
| 4 | 0 | 9″ brickwork to ditto with arched top . . | 22/- | 4 | 8 | 0 |
| | | Carried forward . . . | | £117 | 14 | 0 |

| | | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| yds. Super. | ft. | Brought forward . . . | | 117 | 14 | 0 |
| 1 | 0 | 3″ concrete slab over opening . . . . | 3/- | 0 | 3 | 0 |
| | | *Slaters' Work.* | | | | |
| Squares. Super. | ft. | | | | | |
| 8 | 50 | Countess slating, 2½″ lap, including two zinc nails to each slate, laths, and lathing . . . . . . . . . . . | 35/- | 14 | 17 | 6 |
| Lin. yds. | | | | | | |
| 13 | | Ridge set in cement. P.C. 1*s.* 6*d.* . . . | 2/- | 1 | 6 | 0 |
| 16 | | Cement fillets . . . . . . . . . | 3*d.* | 0 | 4 | 0 |
| | | *Carpenter, Joiner, and Ironmonger.* | | | | |
| Cube ft. | | | | | | |
| 13 | | Fir in 4″ × 2″ wall-plates . . . . . . | 2/- | 1 | 6 | 0 |
| 6 | | „ 4″ × 3″ lintels . . . . . . . | 2/- | 0 | 12 | 0 |
| 70 | | „ 7″ × 2″ joists . . . . . . . . | 2/- | 7 | 0 | 0 |
| 9 | | „ 4″ × 2″ studs, sills, and brace to partition . . . . . . . . . . . | 2/8 | 1 | 4 | 0 |
| 68 | | Fir in 4″ × 2″ ceiling joists and rafters, 5″ × 2″ rafters, and 7″ × 1¼″ ridge . . | 2/6 | 8 | 10 | 0 |
| 7 | | Fir in 4½″ × 3″ wrought rebated beaded and grooved door-frames . . . . . . | 4/- | 1 | 8 | 0 |
| Squares. Super. | | | | | | |
| 7 | 0 | ⅝″ straight-jointed flooring laid folding . | 18/- | 6 | 6 | 0 |
| | 33 | 1½″ bead and butt four-panel doors . . | 1/4 | 2 | 4 | 0 |
| | 97 | 1½″ molded „ „ „ . . | 1/4 | 6 | 9 | 4 |
| | 66 | 1½″ ledged doors . . . . . . . . . | 1/- | 3 | 6 | 0 |
| | 97 | 1½″ ovolo sashes, double hung, oak sunk, weathered and throated sills, deal-cased frames, patent sash-lines, and brass pulleys, including all linings . . . . | 1/3 | 6 | 1 | 3 |
| 1 | 50 | ⅝″ wrought one side eaves and soffit boarding . . . . . . . . . . . | 15/- | 1 | 2 | 6 |
| | 20 | 1″ wrought shelves and bearers to pantry . . . . . . . . . . . | 9*d.* | 0 | 15 | 0 |
| | 56 | 1″ wrought stair-treads and risers . . . | 6*d.* | 1 | 8 | 0 |
| | 12 | 1″ wrought deal seat and riser to w.c. and bearers . . . . . . . . . . | 6*d.* | 0 | 6 | 0 |
| | | Carried forward . . . | | £182 | 2 | 7 |

| yds. | ft. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| Lin. | | Brought forward . . . | | 182 | 2 | 7 |
| 0 | 128 | 6″ × 1¼″ door-linings with 4″ × ½″ stops, including mitres and plugs . . . . | 6*d.* | 3 | 4 | 0 |
| 0 | 25 | 2″ × 1″ rounded window-nosing with returned ends . . . . . . . . . . | 3*d.* | 0 | 6 | 3 |
| 0 | 218 | 7″ × ¾″ Torus skirting, including mitres and stops, plugs, and grounds . . . | 4*d.* | 3 | 12 | 8 |
| 0 | 6 | 3″ × 1″ square ditto to w.c. . . . . . | 2*d.* | 0 | 1 | 0 |
| 0 | 48 | 7″ × ¾″ wrought barge board ditto. . . | 4*d.* | 0 | 16 | 0 |
| 0 | 48 | 3″ × 1″ wrought molding planted on ditto and ditto. . . . . . . . . | 3*d.* | 0 | 12 | 0 |
| 0 | 26 | 9″ × 1½″ wrought strings to stairs ditto . . . . . . . . . . . . . | 6*d.* | 0 | 13 | 0 |
| 0 | 24 | 2″ wrought rounded handrail to ditto and ditto . . . . . . . . . . . . . | 3*d.* | 0 | 6 | 0 |
| 0 | 361 | 2″ × ¾″ wrought architraves „ . | 2*d.* | 3 | 0 | 2 |
| 0 | 96 | 2″ × ¾″ „ splines to living-room walls, including plugs to wall . . . | 2*d.* | 0 | 16 | 0 |
| 0 | 72 | Angle beads for plaster, including plugs to wall . . . . . . . . . . . . | 2*d.* | 0 | 12 | 0 |
| 0 | 60 | Herring-bone strutting to floors . . . | 3*d.* | 0 | 15 | 0 |
| 0 | 81 | Grooves and tongues to stairs . . . . | 2*d.* | 0 | 13 | 6 |
| 0 | 42 | Rounded nosings to ditto . . . . . . | 1*d.* | 0 | 3 | 6 |
| 0 | 76 | Tilting fillet . . . . . . . . . . . | 1*d.* | 0 | 6 | 4 |
| | | 54 housings of treads and risers into strings . . . . . . . . . . . . . | 3*d.* | 0 | 13 | 6 |
| | | 72 ends of rafters cut and wrought . . | 4*d.* | 1 | 4 | 0 |
| | | 1 copper lid . . . . . . . . . . . | 2/6 | 0 | 2 | 6 |
| | | 1 dresser, 4′ wide, with cupboard, and 2 drawers, 2′ deep, and 4 shelves, 1′ deep, complete . . . . . . . . . | £2 | 2 | 0 | 0 |
| | | 1 pale and space-gate, 3′ opening, with two posts, each 6′ long and 4″ square . | 12/- | 0 | 12 | 0 |
| | | 1 hole dished in w.c. seat . . . . . . | 1/- | 0 | 1 | 0 |
| | | 8 pairs 3½″ C.I. butts. P.C. 4*d.* . . . | 6*d.* | 0 | 4 | 0 |
| | | 4 „ 14″ **T**-hinges. „ 1/- . . . | 1/3 | 0 | 5 | 0 |
| | | 1 „ 9″ ditto. „ 6*d.* . . . | 9*d.* | 0 | 0 | 9 |
| | | 1 „ gate-hinges. „ 2/6 . . . | 3/6 | 0 | 3 | 6 |
| | | 1 gate-latch. „ 2/- . . . | 2/6 | 0 | 2 | 6 |
| | | Carried forward . . . | | £203 | 8 | 9 |

| | | P.C. | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| | Brought forward . . . | | | 203 | 8 | 9 |
| 2 | Norfolk latches. | P.C. 6*d.* | 9*d.* | 0 | 1 | 6 |
| 5 | 6″ necked bolts. | „ 6*d.* | 1/3 | 0 | 6 | 3 |
| 8 | 6″ iron-rim locks and furniture. | „ 3/- | 3/6 | 1 | 8 | 0 |
| 7 | window-catches. | „ 3*d.* | 4*d.* | 0 | 2 | 4 |
| 4 | buttons to doors. | „ 2*d.* | 3*d.* | 0 | 1 | 0 |
| 12 | hat and coat pegs. | „ 4*d.* | 6*d.* | 0 | 6 | 0 |
| 4 | 2′ register stoves. | „ 7/6 | 9/- | 1 | 16 | 0 |
| 1 | range with oven and sham. | „ 20/- | 30/- | 1 | 10 | 0 |
| 2 | 8″ × 11″ grates to scullery. | „ 9*d.* | 1/- | 0 | 2 | 0 |
| 1 | 6″ × 5″ iron furnace door. | „ 1/3 | 1/6 | 0 | 1 | 6 |
| 1 | 10-gallon G.I. copper. | „ 5/- | 6/- | 0 | 6 | 0 |
| 1 | w.c. removable pan. | „ 9/- | 10/- | 0 | 10 | 0 |
| 1 | dry earth scuttle and shovel. | „ 3/6 | 4/- | 0 | 4 | 0 |

## *Smith and Founder and Plumber.*

| yds. | ft. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| Lin. | | | | | | |
| 0 | 94 | 4½″ O.G. gutter. P.C. 3*d.* . . . . . . | 4*d.* | 1 | 11 | 4 |
| | | 12 stops to ditto . . . . . . . . . . | 4*d.* | 0 | 4 | 0 |
| | | 6 outlets . . . . . . . . . . . . | 1/- | 0 | 6 | 0 |
| 0 | 78 | 2½″ down-pipe. P.C. 3*d.* . . . . . . . | 4*d.* | 1 | 6 | 0 |
| | | 6 swan-neck bends . . . . . . . . . | 2/- | 0 | 12 | 0 |
| | | 6 shoes . . . . . . . . . . . . . | 1/- | 0 | 6 | 0 |
| | lbs. | | | | | |
| | 84 | W.I. 2″ × ½″ chimney bars . . . . . | 3*d.* | 1 | 1 | 0 |
| | | 1 pump to soft-water tank. P.C. 20/- . | 25/- | 1 | 5 | 0 |
| | cwts. | | | | | |
| | 2 | Lead flashings . . . . . . . . . . | 30/- | 3 | 0 | 0 |

## *Plasterer.*

| yds. | ft. | | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
| Super. | | | | | | |
| 202 | 0 | Render float and set walls and twice distemper . . . . . . . . . . | 1/- | 10 | 2 | 0 |
| 19 | 0 | Lath, plaster, float, and set partition and ditto . . . . . . . . . . | 1/6 | 1 | 8 | 6 |
| 80 | 0 | Lath, plaster, float, and set ceilings and ditto . . . . . . . . . . . . | 1/4 | 5 | 6 | 8 |
| | | Carried forward . . . | | £236 | 11 | 10 |

| yds. Super. | ft. |  | @ | £ | s. | d. |
|---|---|---|---|---|---|---|
|  |  | Brought forward . . . |  | 236 | 11 | 10 |
| 16 | 0 | Render cistern in cement 1" thick in two coats, 1 of cement to 3 of sand, finishing with a floating of neat cement $\frac{1}{8}$" thick . . . . . . . . . . . | 1/6 | 1 | 4 | 0 |
|  |  | *Glazier and Painter.* |  |  |  |  |
| 0 | 72 | 16 ozs. glass, 3rd quality and small panes, including glazing. P.C. 3*d*. . | 6*d*. | 1 | 16 | 0 |
| 150 | 0 | Knot, stop, prime, and paint two coats on all woodwork outside and in . . . | 9*d*. | 5 | 12 | 6 |
| Lin. |  |  |  |  |  |  |
| 60 | 0 | Ditto on gutters and down pipes . . . | 3*d*. | 0 | 15 | 0 |
|  |  | *General.* |  |  |  |  |
|  |  | Make good after other trades, scrub floors, clean windows, black stoves, clear away rubbish, repair defects, and maintain for three months, insure against fire, and pay all claims and fees . . . . |  | 5 | 0 | 0 |
|  |  | Total . . . |  | £250 | 19 | 4 |

# APPENDIX M.

## FORM OF CONCESSION.

AGREEMENT made this ——— day of ——— One thousand nine hundred and ——— BETWEEN ——— Secretary of State for the Department of Agriculture and Public Works of the one part, and ——— acting herein for the ——— of the other part, to wit.

1. The Government of ——— hereby grants to ——— hereinafter styled "the Contractors," a Concession for a term of forty years for the construction and working of a Steam-propelled Railway to run from the Port of ——— to ———, passing through ———.

2. On the expiration of the term of concession the Government shall have power to purchase the Railway of the Contractors on a valuation arrived at by experts appointed on both sides.

3. If it did not suit the Government to purchase at the end of the forty years' term, the Concession for working the railway shall be extended for a further term of fifty-nine years, after which time it shall become the property of the Government without payment of any compensation whatever.

4. The Government hereby agrees to allow the Contractors for a term of twenty-five years a Guaranteed interest at the rate of Seven per cent. on such Capital as may be invested in the Undertaking, which Capital it is hereby agreed shall not exceed ———.

5. Sums payable by the Government under the Guarantee clause shall be paid at the end of every successive quarter on production of the Revenue and Expenditure accounts applicable to the working of the Section or Sections open for traffic.

6. The Government, moreover, hereby agrees to give the Contractors a grant of all Public lands lying along the track, and required either for the line itself or for Stations, Shops, or other necessary Works.

7. The Contractors, undertaking shall be declared a work of Public utility, and will as a consequence carry with it power to expropriate to use Springs and all such elements as may be required for the purposes of the Railway line, the Stations, etc., even though owned by members of the Public, subject to a preliminary judicial Order and the payment of indemnities as per valuation made by Experts.

8. The Contractors undertaking shall be entitled to the use of the Government telegraphs and inland Post Office facilities free of charge. The Contractors, moreover, shall be exempted from the necessity of paying Stamp dues in any private Agreements of theirs bearing upon matters connected with their undertaking, and in fact exempt in respect of any dues whatsoever attaching to stamped paper.

9. Throughout the period of construction and the term of the Concession, the Contractors shall be privileged to import free of duty, subject to examination or clearance, all such goods and materials as may be required for the construction, the working, and the maintenance of the line, Stations, Offices, and Shops.

10. All employees in the service of the Contractors shall enjoy exemption from liability to service Civil or Military.

11. The Railway line, the Shops, the land, and all dependencies shall be exempt from imposts Governmental or Municipal (Rates or Taxes).

12. The Government shall allow a term of One year, commencing from the date of the execution of the present Contract, for the Surveys to be completed, subject, however, to the Report of "the Engineer" as to the practicability or impracticability of the thing.

13. The Contractors shall have power to accept or to decline the present Contract within two months from the date of the completion of said Surveys, and they shall be bound to notify their views by means of a Notarial Deed to be handed to the Consul General of the ——— in London, but in case of acceptance they will be required to deposit with the Bank of said City forthwith and to order of the ——— Government the sum of £10,000 by way of guarantee for the completion of the Contract.

14. Four months after the ratification of the Contract by the Contractors, and after depositing the Caution money, the works of construction of the line must be commenced and completed within the three years next following thereupon.

15. Non-payment of the deposit provided for under Section 13 will involve forfeiture of the Concession, and so will failure to commence and complete the works at the dates fixed by Section 14, save and except the intervention of *vis major* (the act of God), but with that single exception the Contract between the parties hereto in case of non-payment or failure to commence and complete as aforesaid would lapse and be forfeited.

16. On acceptance by the Government of the first Section, and after its inauguration for traffic, the Government shall return to the Contractors the sum of £10,000 deposited by way of Caution money.

17. On completion of each Section the Government shall appoint one or more Engineers charged with the duty of inspecting the works for the purpose of ascertaining whether the Contract Conditions have been fully complied with, and in respect of the working of the line there shall be appointed a Government Auditor to verify the Accounts and report on their correctness.

18. The Regulations, the tariff of fares, and the estimates for the Salaries payable to employees of the Railway, shall be settled and agreed upon in due course by a mixed Committee appointed by the Government and by the Contractors, and so soon as passed and sanctioned by the Government they shall come into force and operation.

19. The Contractors shall be bound—

(1) To maintain the line, the Stations, and all dependencies in thorough good repair.

(2) To carry free of charge from any to any point on the line where Stations exist all the Post Office Mail-bags.

(3) To carry Government goods at a reduction of 25 per cent. on the General Tariff.

(4) To carry free of charge individuals belonging to the Government, and Civil Servants travelling on duty.

(5) To carry the Military at a reduction of 50 per cent. on the First-class fares for Officers and on Third-class fares for Private Soldiers.

(6) To make not less than one all-round journey daily.

20. Any difference arising between the Government and the Contractors shall be settled and determined by Judges or Arbitrators in accordance with the laws of the Country without recourse to diplomatic intervention.

21. The domicile of the Contractors shall be the City of London,

and they shall be bound to have an Agent invested with plenary powers at ———.

22. The Contractors shall have power to transfer and assign all rights and obligations attaching to these Presents to any Joint Stock Company formed to carry on the Contract or to any private individual, provided the consent of the Government be first asked and obtained.

23. It shall not be lawful for any foreign Government to become a Shareholder in any Joint Stock Company to be formed as aforesaid.

24. The Undertaking shall be styled ———.

## CONSTRUCTION.

25. The gauge of the line shall be three feet English measurement, the rails of the best **T**-section steel, and to weigh not less than thirty-five pounds per lineal yard.

26. The rails shall be duly and firmly secured to the sleepers by spikes or bolts, their junction fixed by fish-plates, which shall be firmly kept in their place by means of bolts and screw-nuts, the whole being of good and substantial workmanship.

27. The rolling stock shall be such as may be deemed necessary to meet the requirements of the traffic. The maximum gradient and the minimum radius of the curves shall be determined in the course of the survey operations according to the topographic conditions of the ground to be traversed, subject, however, to the limitations recognized by the science of engineering in such matters.

28. The embankment shall be properly ballasted and substantially constructed in every respect.

29. The sleepers shall be at least six feet in length and four inches in thickness.

30. The high roads in the Country shall not be used more than is absolutely necessary, and when necessary, shall be used with all due caution and care.

31. Slopes of cuttings at embankments and excavations shall be of sufficient degree of inclination, and whenever it becomes necessary from the nature of the soil, they must be duly shored up and buttressed according to approved methods for such work.

32. Bridges and Viaducts shall be of iron and wood, and substantial in build.

In Witness whereof, the Contracting parties now hereunto append their Signatures at ——— on this ——— day of ———, 19 .

(Signed)
(Signed)

Having seen the foregoing Agreement made between ——— of ——— and ——— acting in the capacity of Procurator to ——— relative to the construction and the working of a Steam-propelled Railway between the Port of ——— and ———, and finding the said Agreement is in accord with the instructions given to ——— for the purpose, The Supreme Provisional Government hereby grants its full sanction to said Agreement, being, however, under obligation to submit the same for ratification to the present Constituent Assembly.

Seal
Ministry
of
Finance.

(Signed) ———
Secretary of State Finance Department.

The undersigned Ministers of ——— hereby certify that the following is the genuine Signature of the Minister of Finance :—

I, ———, H.B.M. Consul, hereby certify that the signature on the other side ——— is true and authentic. In faith and testimony of which I hereunto subscribe my name and affix my seal of office in ——— this ——— day of ——— in the year of our Lord, 19 .

(Signed) ———
Consul.

British
Consular
Seal.

5/-
Stamp.
No.

# APPENDIX N.

## WEIGHTS AND MEASURES.

*Value of One Pound Sterling in Different Countries.*[1]

| | | | | | |
|---|---|---|---|---|---|
| Great Britain and Colonies | 20·0 | shillings | or | 240 | pence |
| France and Belgium | 25·2 | francs | ,, | 2520 | centimes |
| Spain | 25·2 | pesetas | ,, | 2520 | centimos |
| Italy | 25·2 | liras | ,, | 2520 | centesimi |
| Bulgaria | 25·2 | levas | ,, | 2520 | stotinkis |
| Roumania | 25·2 | leys | ,, | 2520 | banis |
| Servia | 25·2 | dinars | ,, | 2520 | paras |
| Greece | 25·2 | drachmas | ,, | 2520 | lepta |
| Finland | 25·2 | markkas | ,, | 2520 | penni |
| South America, Chili, and Argentine | 5·05 | pesos [2] | ,, | 505 | centavos |
| Mexico | 4·64 | ,, | ,, | 464 | ,, |
| Portugal | 4·5 | milreis | | | |
| United States | 4·87 | dollars | ,, | 487 | cents |
| Germany | 20·4 | marks | ,, | 2040 | pfennige |
| Russia | 6·3 | roubles | ,, | 630 | kopecks |
| Denmark, Sweden, and Norway | 18·2 | crowns | ,, | 1820 | öre |
| Austria-Hungary | 24·0 | ,, | ,, | 2400 | hellers |
| Holland | 12·0 | florins | ,, | 1200 | cents |
| Turkey | 1·107 | pounds | ,, | 110 | piastres |
| Egypt | 0·985 | ,, | ,, | 98·5 | ,, |
| Brazil | 8·9 | milreis | | | |
| China | 3·07 | taels | ,, | 3070 | cash |
| India | 15·0 | rupees [3] | ,, | 240 | annas |
| Indo-China | 4·8 | piastres | | | |
| Japan, Hong Kong, and the Straits Settlements | 9·76 | yen | ,, | 976 | sen |
| Persia | 34·0 | khrans | ,, | 680 | shahis |
| Siam | 8·3 | ticals | | | |
| Tunis | 40·3 | piastres | | | |

---

[1] Whitaker's Almanack.

[2] A peso is 5 francs. The above figures are only approximate, as the rate of exchange varies, the Italian lira, though nominally the same, being of less value than the French franc.

[3] Variable. This is on the basis of silver at 5*s.* per oz.

# APPENDIX O.

## LINEAL MEASURE.

One yard = 3 feet = 36 inches
„ fathom = 6 „ = 18 hands
„ chain = 66 „ = 100 links
„ mile = 8 furlongs = 80 chains
„ league = 3 nautical miles = 18,248 feet
„ degree = 60 „ „ = 69·121 miles
„ Admiralty knot = 6080 feet = 2432 military paces
„ cable = 100 fathoms = 200 yards
„ kilometre = 3280·9 feet = 0·6214 mile
„ metre = 3·2809 „ = 39·3708 inches
„ centimetre = 0·0328 „ = 10 millimetres

A halfpenny is 1 inch in diameter, a sixpence 0·75 inch.

# APPENDIX P.

## SUPERFICIAL MEASURE.

One square = 100 sq. feet = 9·29 sq. metres or centiares
„ yard = 9 „ = 108 twelfths (not inches)
„ acre = 4 roods = 160 poles
„ „ = 10 sq. chains = 4840 yards
„ hectare = 100 ares = 10,000 sq. metres or centiares
„ „ = 2·471 acres = 11,960 sq. yards

# APPENDIX Q.

## SOLID MEASURE.

One cubic yard = 27 cubic feet = 324 twelfths (not inches)

„ „ foot = 6·23 gallons = 0·78 bushel

„ coombe = 4 bushels = 32 gallons

„ quarter = 8 „ = 10·264 cubic feet

„ barrel = 36 gallons = 288 pints

„ chaldron = 12 sacks = 48 bushels coke

„ ton = 35 cubic feet displacement

„ ton shipping = 40 „ merchandise

„ „ „ = 42 „ timber

„ load timber = 50 „ squared = 40 cubic feet unhewn

„ St. Petersburg standard = 165 „

„ litre or cubic decimetre = 61·027 cubic inches = 10 decilitre

„ ditto = 100 centilitre = 1000 millilitre

„ stere or cubic metre = 35·32 cubic feet = 1000 litre

„ rod of brick-work = 408 feet super one brick thick

„ ditto = 272 feet super one brick and a half thick

„ ditto = 11·33 cubic yards

„ hod of mortar = 0·75 „ foot = 0·5 bushel

„ stack of wood = 216 „ feet = 1 fathom

# APPENDIX R.

## MEASURES OF WEIGHT.

One ton English = 20 cwt. = 2240 lbs.
„ „ American = 20 „ = 2000 „
„ „ French = 1000 kilograms = 2204·6 „
„ quarter English = 28 lb. = 448 ozs.
„ gramme French = 0·0022 lb.
„ barrel of gunpowder = 100 lbs.
„ faggot of steel = 120 „
„ pig of ballast = 56 „
Three pennies (approx.) = 5 halfpennies = 1 oz.

# APPENDIX S.

## MISCELLANEOUS.

One gallon of water weighs 10 lbs.
„ cubic metre of water „ 1000 kilograms
„ „ foot „ „ 62·23 lbs.
„ „ „ of salt water „ 64 „
„ square foot wrought iron 1 inch thick „ 40 „
„ „ cast „ „ „ 39 „
„ „ steel „ „ 41 „
„ „ tin or zinc „ „ 38 „
„ „ copper „ „ 46 „
„ „ lead „ „ 59 „
„ bushel wheat „ 63 „
„ „ barley „ 55 „
„ „ oats „ 42 „
„ „ maize „ 60 „
„ cubic foot of clay „ 126 „
„ „ „ limestone „ 140 „
„ „ „ granite „ 168 „
„ „ „ fir „ 35 „
„ „ „ pitch-pine „ 42 „

One ream of paper = 20 quires = 480 sheets
„ hundred deals = 120
„ horse-power (HP.) = 33,000 lbs. raised 1 foot high per minute

# APPENDIX T.

## MENSURATION.

Area of a circle = radius squared × 3·1416, *i.e.* $= \pi r^2$

Circumference of a circle = diameter × 3·1416, „ $= 2\pi r$

Contents of a pyramid = area of base × height ÷ 3, „ $= \pi r^2 \frac{h}{3}$ for a cone

Contents of a sphere $= 4{\cdot}1888 r^3$ $= \frac{4}{3}\pi r^3$

Surface of a sphere = diameter$^2$ × 3·1416 $= 4\pi r^2$

Cubical contents of a tree $= \text{length}\left\{\frac{g_1+g_2+g_3}{12}\right\}^2$, where $g_1$, $g_2$, $g_3$ are the girths at the centre and ends

In the right-angled triangle (Fig. 84)—

$$\sin a = \frac{p}{h}, \quad \cos a = \frac{b}{h}, \quad \tan a = \frac{p}{b}$$

$$\operatorname{cosec} a = \frac{h}{p}, \quad \sec a = \frac{h}{b}, \quad \cot a = \frac{b}{p}$$

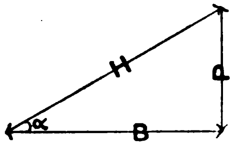

*FIG. 84.*

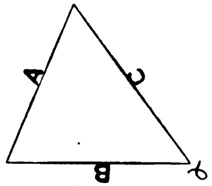

*FIG. 85*

In the triangle (Fig. 85)—

$$A = B\frac{\sin a}{\sin B}$$

$$\text{Also } \sin a = \tan a \cos a = \frac{\tan a}{\sec a} = \frac{1}{\operatorname{cosec} a}$$

Circumference of the earth = 24,855 miles.

# APPENDIX U.

## Electrical Measurements.

| | | | | |
|---|---|---|---|---|
| The | ampere | is the unit | of | current |
| „ | coulomb | „ | „ | quantity |
| „ | volt | „ | „ | electromotive force or difference of potential |
| „ | ohm | „ | „ | resistance |
| „ | watt | „ | „ | power |
| „ | kilowatt-hour | „ | „ | work |

**The Electromotive Force (E.M.F.)** generated by a Daniel's cell, or, to put it another way, the Difference of Potential (**P.D.**) between the poles of the cell, is a little more than a **Volt.**

When the poles are connected, what is *called* a flow of electricity takes places from one to the other, and against this there is a resistance inside the cell as well as outside in the connecting wire, and this is expressed in **Ohms.**

The volume of the current depends directly on the **P.D.** and inversely on the resistance. If the **P.D.** (or **E.M.F.**) is 1 volt, and the resistance is 1 ohm, the volume of the current will be 1 **Ampere,** *i.e.* 1 **Coulomb** per second; and if the P.D. is 10 volts, and the resistance 5 ohms, the current will be 2 amperes, or a coulomb in half a second.

An *International* or True **Ohm,** which differs slightly from the old **B.A.** (British Association) unit, and also from the French *Legal* Ohm, is the resistance that a column of mercury, 106·3 centimetres long and 1 square millimetre in section, offers to the current, mercury being taken as the standard, because a very little impurity in copper makes a considerable difference to its conductivity.

The following table gives the resistances of some of the metals in ohms for certain lengths and sectional areas :—

| **Length . . . .**<br>**Sectional area . .** | **1 metre.**<br>**1 square millimetre.** | **1 metre.**<br>**1 square inch.** | **1 yard.**<br>**1 square inch.** |
|---|---|---|---|
| Mercury . . | 0·941 | 0·001411 | 0·001290 |
| Lead . . . . | 0·192 | 0·000288 | 0·000264 |
| Iron . . . . | 0·096 | 0·000144 | 0·000132 |
| Copper . . . | 0·016 | 0·000024 | 0·000022 |
| Silver . . . | 0·015 | 0·000023 | 0·000021 |

The resistance of a conductor varies directly as its length and specific resistance and inversely as its sectional area, so that the resistance of a copper wire 100 metres long and 5 square millimetres in sectional area would be 100 × 0·016 ÷ 5, *i.e.* 0·32 ohm, or, if the wire was of iron, 100 × 0·096 ÷ 5, *i.e.* 1·98 ohm.

The following table for copper wires will be found useful:—

| **Standard wire gauge.** | **Diameter in inches.** | **Weight in lbs. per mile.** | **Area in square inches.** | **Area in square millimetres.** | **Resistance in ohms per mile.** |
|---|---|---|---|---|---|
| 7/0 | 0·500 | 4000 | 0·194 | 126·7 | 0·219 |
| 6/0 | 0·464 | 3440 | 0·169 | 109·1 | 0·255 |
| 5/0 | 0·432 | 2980 | 0·146 | 94·6 | 0·294 |
| 4/0 | 0·400 | 2560 | 0·126 | 81·1 | 0·343 |
| 3/0 | 0·372 | 2220 | 0·109 | 70·1 | 0·396 |
| 2/0 | 0·348 | 1940 | 0·095 | 61·4 | 0·453 |
| 0 | 0·324 | 1680 | 0·082 | 53·2 | 0·522 |
| 1 | 0·300 | 1440 | 0·070 | 45·6 | 0·609 |
| 2 | 0·276 | 1220 | 0·060 | 38·6 | 0·720 |
| 3 | 0·252 . | 1020 | 0·050 | 32·2 | 0·863 |

An **Ampere** (or **Coulomb** of electricity per second) can be measured by the chemical action it produces.

| | | | |
|---|---|---|---|
| One coulomb sets free from water | 0·0000104 | gramme of | hydrogen |
| „ „ deposits | 0·0003280 | „ | copper |
| „ „ „ | 0·0011180 | „ | silver |
| „ „ dissolves | 0·0003367 | „ | zinc |

Assuming that the resistance inside a cell is 2 ohms, and that the poles are connected by a copper wire a square millimetre in section 62·5 metres long, the resistance of which would be 1 ohm (since 0·016 × 62·5 = 1), the volume of the current given out will be $\frac{1 \text{ volt}}{(2 + 1) \text{ ohms}} = \frac{1}{3}$ ampere = 1 coulomb in 3 seconds.

To put this generally—

Let C be the volume of the current in amperes
„ E „ E.M.F. or P.D. in volts
„ $r$ „ internal resistance of the cell in ohms
„ R „ external „ „ wire „
„ $n$ „ number of cells

Then, if the cells are in *series, i.e.* if the positive of one is connected with the negative of the next—

$$C = \frac{nE}{nr + R} = \frac{E}{r} \text{ approximately for a short circuit}$$

$$= \frac{nE}{R} \quad \text{„} \qquad \text{„ long „}$$

But if the cells are in parallel, *i.e.* if all the positives and negatives are respectively connected together so that the $n$ cells really make one large cell—

$$C = \frac{E}{\frac{r}{n} + R} = \frac{nE}{r} \text{ approximately for a short circuit}$$

$$= \frac{E}{R} \quad \text{„} \qquad \text{„ long „}$$

The power of a current depends not only on its volume, but also on the pressure or difference of potential, just as the power of a stream of water depends not only on the discharge, but also on the fall. The quantity of water flowing through a pipe varies inversely as the resistance (which depends on the sectional area and length of the pipe) and directly as the pressure; so its power varies inversely as the resistance, and directly as the *square* of the pressure or "head."

If, therefore, C is the current, E the E.M.F., and R the resistance, the power is CE, which is equal to $\frac{E^2}{R}$.

The power a current of 1 ampere acted on by a P.D. of 1 volt is called a **Watt.**

The work done in raising 33,000 lbs. a foot high, or 33 lbs.

1000 feet high per minute, is called a **Horse-power** (HP.), and is equivalent to 746 watts, so that a current of 74·6, amperes, acted on by a P.D. of 10 volts, will develop 1 horse-power.

If a current of 10 amperes was induced by a pressure of 100 volts, it would show that the resistance was 10 ohms—

$$\text{since } C = \frac{E}{R} = \frac{100}{10}$$

and its power in watts would be—

$$100 \times 10 = 1000 = 1 \text{ kilowatt, or, approximately, } 1\tfrac{1}{3} \text{ HP.}$$

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